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RAIN EFFECTS ON RADIO FREQUENCY PROPAGATION

D.J. FANG AND C.S. LO

WASHINGTON DIVISION
MASSACHUSETTS TECHNOLOGICAL LABORATORY

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FINAL REPORT

SEPTEMBER 1985 - MAY 1986

PREPARED FOR

HQ BALLISTIC MISSILE OFFICE/MYES
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Rain is a principal cause of signal degradation in a terrestrial or satellite transmission in a frequency range from UHF to EHF. This study proceeded with a format for compiling and editing the relevant data, and for making engineering inferences to supplement relevant yet inadequate data, as required for practical applications on a terrestrial or a slant path link. The format was to model the rain-induced attenuation by an empirical relationship of $a \doteq aR^b L$ type of power law equation. Five well recognized models (CCIR, Fedi, French, Lin and SAM) were chosen for comparison with database.

As for immediate applications, the Lin model is recommended for percentage of time over 0.3% of a year; and for percentage of time less than 0.3%, the French model is considered to be applicable. For more specific applications, such as for cases of low rain-rate regions to high rain-rate regions, low elevation angle paths to high elevation angle paths, etc., best performance models are identified according to Table 6-12 of the report.

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List of Abbreviations, Acronyms and Symbols

A = Attenuation, dB

a = Empirical Attenuation Coefficient

a_H = Horizontal Polarized Value of a

A_m = Measured Attenuation, dB

A_p = Predicted Attenuation, dB

A_S = Specific Rain Attenuation, dB/km

a_V = Vertical Polarized Value of a

$A_{0.01}$ = A at 0.01%

B = Satellite Beacon

b = Empirical Attenuation Index

b_H = Horizontal Polarized Value of b

b_V = Vertical Polarized Value of b

C = Circular Polarization

CCIR = International Radio Consultative Committee

C_f = Correction Factor (Fedi Model)

D = Distance between Transmitter and Receiver

dB = Deci-bel

dBW = dB over 1 watt

d_i = The Difference Between A_p and A_m

DOD = Department of Defense

EHF = Extremely High Frequency

E_m = Actual Electric Field in a Medium, volt/meter

E_o = Pseudo-Electric Field if the Medium is a Free Space

F = Correction Factor

f = the frequency, GHz

F_p = Reduction Factor for P% of Time

$F_{0.01}$ = F_p at 0.01%

GHz = Giga-Hertz

G_r = Receiving Antenna Gain, no unit or dB

G_t = Transmitting Antenna Gain, no unit or dB

H = Horizontal Polarization

h_i = The 0°C Isotherm Height

H_o = Height above Mean Sea Level, km

H_r = the Rain Height, km

ITU = International Telecommunications Union

IWP = International Working Party

K_r = Path Reduction Coefficient (Lin Model)

L = Equivalent Path Length, meter

L_c = Horizontal Projection of L_s

L_e = Effective Path Length, km

L_o = Free Space Loss, dB

L_p = Medium Loss, dB

L_s = Slant Path Length, km

MTL = Massachusetts Technological Laboratory

P_r = Received Power, watt or dBW

P_t = Transmitted Power, watt or dBW

R = Radiometer, Sky Noise

R = Rain Rate, mm/hr

RF = Radio Frequency

RZ = Rain Zone

$R_{0.01}$ = Point Rainfall Rate at 0.01% of an Average Year, mm/hr

[illegible] = Radiometer, Sun Tracker

S = Standard Deviation Score

SAM = Simple Attenuation Model

SBIR = Small Business Incentive Research

T = Type of Measurement

UHF = Ultra High Frequency

US = United States

V_i = Test Variable

V = Vertical Polarization

Φ = the latitude

λ = Wavelength, m

μ_v = Standard Deviation of V_i

τ = Polarization Tilt Angle

π = 3.1415926

σ_v = Mean of V_i

Θ = Path Elevation Angle

1. Introduction

This final report addresses rain effects on radio frequency (RF) propagation, an important concern raised by the US Air Force in the 1985 DOD/SBIR solicitation. In the solicitation, the Air Force pinpoint the issue as:

Numerous studies have been previously conducted on this subject and vast amount of data exist in this regard; however, a wide range of uncertainty exists and the communications system designer is confronted with conflicting data. Using existing rain propagation data, it is possible to show any condition from complete link outage to one of minimal or no effect.

The Massachusetts Technological Laboratory (MTL) undertakes the assignment of studying rain effects on radio frequency propagation under contract F04704-85-C-0144. MTL pursues the principal objective of collecting, compiling and correlating all existing obtainable data and, using the latest analytical techniques, analyze rain effects and establish recommended procedures for the evaluation of rain effects to aid communication system design. It is believed that as a result of the work, the crucial issue raised by Air Force has been resolved.

2. Task Overview

Realizing not all readers of this report are communication engineers involved in details of rain effects on microwave systems, we provide an overview of the task so that a reader can put the subject in a proper context from the beginning.

2.1 The Link Budget and the Medium Loss

The link budget is a fundamental concept as required for designing a radio system, irrespect of whether it is a communication system, a navigation system, a remote-sensing system, a surveillance system or an interference system. To start with, the propagation of radio waves in a free space from a transmitter to a receiver is governed by a fundamental equation:

$$P_r = \frac{P_t G_t G_r \lambda^2}{(4\pi D)^2} \tag{1-1}$$

where subscripts t and r refer to transmitting and receiving antennas, respectively, P is the power (watts), G is the gain over an isotropic antenna (numeric ratio), λ is wavelength (meters) and D is distance between transmitter and receiver (meters). If the propagation path is not in a free space, the medium effect can be included by a correction factor F such that

$$P_r = \frac{P_t G_t G_r \lambda^2}{(4\pi D)^2} |F|^2 \tag{1-2}$$

Since P is proportional to the square of the electric field, the factor F is obviously a numeric ratio of actual electric field E_m as a result of the presence of the medium to the pseudo-electric field E_o if the medium is only a free space, i.e.,

$$F = \frac{E_m}{E_o} \tag{1-3}$$

Both E_m and E_o are in volts/m.

For practical engineering applications, one often writes equation (1-2) in an algebraic form:

$$P_r = P_t + G_t + G_r - L_o - L_p \tag{1-4}$$

P_r = received power, dBW

P_t = transmitted power, dBW

G_t = transmitting antenna gain, dB

G_r = receiving antenna gain, dB

L_o = free space loss, dB

L_p = medium loss, dB

The free space loss is given by

$$L_o = 10 \log \frac{4 \pi D^2}{\lambda} \tag{1-5}$$

The medium loss, L_p, is related to the F factor by:

$$L_p = -10 \log |F|^2 \tag{1-6}$$

In radio wave propagations, the medium almost invariably behaves as an attenuator and phase distortor, in the sense that the factor F is less than unity in magnitude. It follows that L_p is generally a positive number.

Details of the link budget will not be presented here as it is availa!le in many textbooks and standard engineering handbooks in communications. See for example the ITT (1977) handbook, Feher (1983), GTE (1970) handbook, and FCC Rules and Regulation.

For the purpose of overview, it suffices to be noted that in the link budget equation (1-4), all parameters are fixed numbers based on the radio

system configuration in concern expect the medium loss L_p, which is a random variable. The magnitude of L_p is always significant to the extent that it actually determines the system limit of a radio system. The medium loss is contributed by many effects, all of which are functions of frequency, geometry, environment, and other complicated factors. Consequently, a correct assessment of L_p is essential in determining the performance of a radio system for applications in communications, navigations, remote-sensings, surveillance and electronic warfares.

2.2 Contributors of L_p

There are many effects which contribute to L_p. For the frequency range from UHF to EHF as cited by the Air Force, the following effects are important:

(a) signal attenuation due to rain-induced electromagnetic wave absorption and scattering,

(b) signal depolarization due to rain; attenuation and depolarization due to other types of hydrometeors,

(c) absorption in atmospheric gases; emission noise from absorbing media,

(d) loss of signal due to beam-divergence of the earth-station antenna as well as due to the normal refraction in the atmosphere,

(e) a decrease in effective antenna gain, due to phase decorrelation across the antenna aperture, caused by irregularities in the refractive-index structure,

(f) relatively slow fading due to beam-bending caused by large-scale changes in refractive index,; more rapid fading (scintillation) and variations in angle of arrival, due to small-scale variations in refractive index,

(g) limitations in bandwidth due to multiple scattering or multipath ef-

fects, especially in high-capacity digital systems,

(h) attenuation and multipath fading by terrain, sea surface or the local environment of the ground terminal (buildings, trees, etc.).

The effects from (d) to (g) are all related to the refractive index structures of the medium. The medium here refers not only to the troposphere but also to the ionosphere. As a matter of fact, for waves below 10 GHz propagating through an ionosphere, these effects can be specifically regrouped as:

(i) rotation of the plane of polarization (Faraday rotation),

(j) dispersion and multipath, which results in a differential time delay across the bandwidth of the transmitted signal,

(k) excess time delay,

(l) scintillation, which affects amplitude, phase and angle-of-arrival of the received signal.

The physics and system implications of each one of the effects are complicated and are beyond the scope of the present study. For interested readers, we refer to a few classical literature given by Kerr (1951), Fock (1965), Beckman and Spizzichino (1963), Davis (1965) and Oguchi (1983). For the purpose of the study, it suffices to ask the most important question:

"Are all these effects equally significant and hence are to be considered in all radio systems?"

The answer is no. Depending on system configurations and applications, different effects manifest themselves to be the dominate signal degradation effects. For example, multipath effect is most harmful to a transmission system operated at low elevation angles; ionospheric scintillation is detrimental to systems at frequencies from UHF all the way to C-band if propagation paths penetrated F-region ionization anomalies at equatorial or at

auroral regions; the excess random time delay is highly undesirable for a navigation system in determining the range and location; and the non-stationary properties of the medium is a prime concern for a radar surveillance system which has a requirement of setting proper dwell time when sweeping through the space; etc.

These examples therefore suggest that there is a general priority order among all the effects. In fact, for the frequency range mentioned by the Air Force, from UHF to EHF, the rain-induced signal attenuation listed as (a) has been known to be the first order effect. Hence, it is generally required that the effect be examined for all radio systems. The reason is rather straight forward, when rain comes it often forcibly blank out the entire signal transmission. The study of rain attenuation effects on radio frequency propagations is therefore the most crucial one in the assessment of L_p.

3. General Approach in Rain-Induced Attenuation Studies

3.1 Analytic Approaches

Once we recognize that rain is a principal cause of signal attenuation in terrestrial and satellite transmission links in a frequency range from UHF to EHF, it can be shown that most of the current studies on microwave propagation through rain follow three steps:

(1) analysis of forward scattering for a plane electromagnetic wave incident upon a single raindrop,

(2) calculation of the diffraction of the wave penetrating perpendicularly across a thin layer of precipitation,

(3) multiple-layer iterative integration to derive the wave field which passes through a precipitation medium.

Papers indicating the scientific and technical findings obtained from all or part of these steps are numerous. Interested readers are referred to a review article by Oguchi (1983) in which some three hundred articles are cited. Some of these papers provide experimental data to substantiate the theoretical findings. Thus, theoretical studies are not only important in the elucidation of the physics of electromagnetic waves propagating through precipitation, but also for establishing valid frameworks within which experimenters can apply and interpret the data collected from the various propagation experiments. On the other hand, for an engineer involved in estimating propagation parameters for the design of a specific microwave link, the results of existing theoretical studies are generally found to be inadequate and/or inapplicable.

A review of the literature reveals many limitations in the theoretical studies. For instance, in step (1), the numerical methods of matching the boundary conditions for a spherical raindrop are so tedious and expensive that only a very limited number of computations of forward scattering fields for selected frequencies, drop sizes, and drop temperatures have been per-

formed (Fang [1978], Evans et al., [1977], Oguchi [1977], Morrison and Cross [1974]). Also, in most computations, the propagation direction is assumed to be perpendicular to the raindrops' axes of symmetry, which renders the results inapplicable to slant path propagation. For step (2), the Laws and Parsons drop size distribution has been used consistently for simplicity, although it is now known that other distributions, such as the Marshall-Palmer and Joss distributions may be more realistic for heavy storms (Laws and Parsons [1943], Levin [1954], Marshall and Palmer [1948], Pruppacher and Pitter [1971], Sekhon and Srivastava [1971], Waldvogel [1974], Fang [1982]). In step (3), the analysis is generally based on the electric field differentials from one layer to the next without including dispersion effects (Fang [1975], Medhurst [1965], Oguchi [1983]). These shortcomings, together with the meteorological uncertainties, such as the spatial rain distribution along a propagation path, provide inadequate building blocks for engineering design applications. All these have been clearly documented by Fang in his Radio Science Article [1982].

On the basis of available theoretical results, our study proceeds with a format for compiling and editing the relevant data, and for making engineering inferences to supplement relevant yet inadequate data, as required for practical applications on a terrestrial or a slant path link. The format is to model the rain-induced attenuation by an empirical relationship of

$$A = aR^b L \tag{3-1}$$

type of power law equation with the indices of a and b determined either theoretically through the three steps described above or experimentally, and with L, the so-called equivalent path-length, determined empirically.

Such a power-law relationship as been widely accepted in the scientific and engineering community [Fang, 1982; Olsen et al., 1978; Crane, 1980; Harden et al., 1978; Fedi, 1979]. The only problem, which is really a complicated one, is that values of a, b and L are so divergent from one theoretical study to the other and from one data source to the other that one often times has the difficulty of picking the proper set. As such,

there are numerous models available which are substantially different from one another. This is the fundamental source of confusion. The Air Force stated the case most appropriately:

"Numerous studies have been previously conducted on this subject and vast amount of data exist in this regard; however, a wide range of uncertainty exists and the communications system designer is confronted with conflicting data. Using existing rain propagation data, it is possible to show any condition from complete link outage to one of minimal or no effect."

The prime effort here is therefore to reconcile data, theories and models such that one can establish recommended procedures for the evaluation of rain attenuation effects governed by equation (3-1).

3.2 The Power Law Relationship

The general empirical power-law relationship as given in equation (3-1) evaluates rain-induced attenuation, A in dB, as produced by precipitation at a rain rate of R mm/hr. The underline modeling assumption is that the rain cell is spatially uniform over a volume such that the radiowave penetration distance over the cell is L in kilometers. This assumption is obviously not a realistic one since a rain cell is not spatially uniform at any time, and even if a rain cell is uniform, it moves randomly such that the path length L is not a physically definitive quantity. Indeed, if one employes equation (3-1) for the evaluation of attenuation, A, based on an instantaneously measured value of R, the answer will be far from the measured A most of the time, irrespect of what set of values of a, b and L are being employed. In short, the equation (3-1) generally does not make sense on event basis.

Fortunately, in planning a radio system, the actual design concern is not on a single event basis but on statistical-averaged basis. Thus, the quantity R refers not to a precipitation rate measured at a given instant, but rather, to a threshold value over a cumulative period of time. And likewise, the parameter A to be derived also refers to a threshold value over the same cumulative period of time. If the cumulative period is sufficiently long, say over a year or over the most wet month of a year (general-

ly known as the worst month), statistical assembles can average out both spatial and temporal non-uniformities. As a result, equation (3-1) becomes sensible. The quantity L simply becomes a statistically averaged proportionality constant of the ratio of attenuation A, as prescribed at a given percentage of time over a year, to the quantity aR^b, with R being the rain-rate prescribed in the same sense.

The beauty of the power law relationship is that by equating A and R according to equation (3-1), the quantity L is almost truly an independent constant. This means A and aR^b are almost balanced out in functional dependence such that the quantity L is, in an ideal case of course, insensitive to frequency, polarization, location, rain type, the percentage of time prescribed, and other electromagnetic/meteorological parameters. In this paper, we are not going to discuss as to how this feature of L comes about. Interested readers are referred to the article by Fang published in Radio Science, [1982].

As long as one is talking about the ideal case, L is not an electromagnetic/meteorological sensitive parameter. It is then only natural to name it as the equivalent path length which does not have a an implied functional dependence in electromagnetic and/or meteorological sense. The temptation, now obvious to the radio wave propagationists, is to model this L based on some intuitively physical considerations. For instance, one may consider rain cell is basically a cylinder with a ceiling height of 4 kilometers, and the equivalent path length is nothing but the radio line-of-sight path penetrating the cylinder. Different propagationists based on different configurational philosophy come up with different expressions of L. This is the centerpiece of the difference among all models.

We are not going to present the philosophy of various models in deriving their respective L, as this is not the concern cited by the Air Force. In the sequal, we simply present L as it is from leading models, and compare the merit and shortcomings of each model with most updated experimental data.

3.3 Numerical Values of a And b

There are many sets of a and b for use in equation (3-1). The differences are mainly results of (i) numerical technique employed for the evaluation of a raindrop scattering coefficients, (ii) the geometry of a raindrop, (iii) dielectric constant expressions, and (iv) assumptions of raindrop temperature [Fang, 1982]. For modeling purpose, the differences are not critical simply because the factor L takes care of scaling anyway.

For this reason, we only consider the set of a and b recommended by CCIR report 721 [1982]. The set can be divided into two cases, one for horizontally polarized transmission, as denoted by a subscript H, and the other for vertically polarized transmission, as denoted by a subscript V. The values are given in Table 3-1, all for terrestrial propagation configurations.

For the case of slant path propagation, either at linear or circular polarization, the coefficients in equation (3-1) can be derived from the values in Table 3-1 using approximate scaling equations given below:

$$a = [a_H + a_V + (a_H - a_V) \cos^2\theta \cos 2\tau]/2 \tag{3-2}$$

$$b = [a_H b_H + a_V b_V + (a_H b_H - a_V b_V) \cos^2\theta \cos 2\tau]/2a \tag{3-3}$$

where θ is the path elevation angle and τ is the polarization tilt angle relative to the horizontal. If a detailed information regarding to τ is not available, use $\tau = 0°$ for horizontal polarization, $\tau = 90°$ for vertical polarization and $\tau = 45°$ for circular polarization.

Table 3-1

Coefficients of a and b as recommended by CCIR Report 721

Frequency (GHz)	a_H	a_V	b_H	b_V
1	0.0000387	0.0000352	0.912	0.880
2	0.000154	0.000138	0.963	0.923
4	0.000650	0.000591	1.121	1.075
6	0.00175	0.00155	1.308	1.265
7	0.00301	0.00265	1.332	1.312
8	0.00454	0.00395	1.327	1.310
10	0.0101	0.00887	1.276	1.264
12	0.0188	0.0168	1.217	1.200
15	0.0367	0.0335	1.154	1.128
20	0.0751	0.0691	1.099	1.065
25	0.124	0.113	1.061	1.030
30	0.187	0.167	1.021	1.000
35	0.263	0.233	0.979	0.963
40	0.350	0.310	0.939	0.929
45	0.442	0.393	0.903	0.897
50	0.536	0.479	0.873	0.868
60	0.707	0.642	0.826	0.824
70	0.851	0.784	0.793	0.793
80	0.975	0.906	0.769	0.769
90	1.06	0.999	0.753	0.754
100	1.12	1.06	0.743	0.744
120	1.18	1.13	0.731	0.732
150	1.31	1.27	0.710	0.711
200	1.45	1.42	0.689	0.690
300	1.36	1.35	0.688	0.689
400	1.32	1.31	0.683	0.684

4. Model Descriptions

4.1 CCIR model

The CCIR model [1985], just like any other CCIR/ITU documents, is derived by consensus among international scientists participating CCIR functions and meetings. Under the stamp of ITU, the CCIR model carries the most significant weight as compared to any other models. It is generally recognized as "the" model for international telecommunications applications. Another important feature of the CCIR model is that because of CCIR's international stature, the model incorporates the most extensive and up-to-date database supplied and supported by all UN member countries around the world. This is the reason we use the CCIR database as "the" database for comparing all models.

The latest CCIR model resulted from the final meeting of CCIR study group 5 at Geneva in September 1985. The formal documentation of the meeting is still in preparation and is thus not yet available to the public. However, Dr. D.J. Fang of MTL, a member of US delegation to CCIR, has an access to the meeting minutes which included document 5/376, title "Draft Revision of Report 564-2, Propagation Data and Prediction Methods Required for Earth-Space Telecommunications Systems". Except editorial changes, this document is known to be the internationally approved final text of the latest CCIR model. The following description of the model is based on document 5/376.

The basic equation is the same as equation (3-1), except it includes an additional reduction factor F_P, i.e.,

$$A(P) = A_s \, L_s \, F_P \tag{4-1}$$

where $A(P)$ = attenuation at P% of time in a year, (dB)

A_s = specific rain attenuation, (dB/km)

L_s = slant path length, (km)

F_P = reduction factor for P% of time

The specific rain attenuation, A_s, is related to rain-rate at P% of time,

$R(P)$ in mm/hr, by the power law equation $aR(P)^b$; the a and b coefficients are described in equations (3-2) and (3-3).

To calculate the long-term statistics of the slant-path rain attenuation A(P) at a given location, the following parameters are required as input.

- $R_{0.01}$: the point rainfall rate for the location for 0.01% of an average year (either direct input or derived from the method given subsequently in Chapter 5).
- H_o: the height above mean sea level of the earth station (km)
- θ : the elevation angle
- τ : polarization tilt angle
- ϕ : the latitude of the earth station
- f : the frequency (GHz)

The method consists of the following steps 1 to 7 for predicting the attenuation exceeded for 0.01% of time and step 8 for other time percentages.

Step 1 - Evaluation rain height H_r in km. The rain height, H_r (km), corresponding to a time percentage of P=0.01% is expressed in terms of latitude, ϕ (degree), by

$$H_r = \begin{cases} 0.4 & ; \quad \phi < 36° \\ 0.4 - 0.075\,(\phi - 36) & ; \quad \phi > 36° \end{cases} \tag{4-2}$$

Step 2 - Evaluate slant path length L_s in km.

$$L_s = \begin{cases} (H_r - H_o)/\mathrm{SIN}\,\theta & ; \quad \theta \geq 5° \\ 2(H_r - H_o) \Big/ \left\{ \left[\mathrm{SIN}^2\theta + \dfrac{2\,(H_r - H_o)}{8500} \right]^{1/2} + \mathrm{SIN}\,\theta \right\} & ; \quad \theta < 5° \end{cases} \tag{4-3}$$

Step 3 - Calculate the horizontal projection of the slant path length in km:

$$L_c = L_s \cos\theta \qquad (4\text{-}4)$$

Step 4 - Evaluate the path reduction factor, F_p, corresponding to 0.01 % of the time:

$$F_p = F_{0.01} = 1/(1 + L_c/22.5) \qquad (4\text{-}5)$$

Step 5 - Determine the rain rate, R(P), exceeded for 0.01% of an average year, (with an integration time of 1 min). If this information cannot be obtained from local data sources, an estimate can be obtained from maps of rain climates as given in Chapter 5 of this report.

Step 6 - Obtain the specific attenuation, A_s, using the frequency-dependent coefficients given in equations (3-2) and (3-3), and the rainfall rate, R, determined from Step 5.

$$A_s = aR(P)^b \quad \text{dB/km} \qquad (4\text{-}6)$$

Step 7 - The attenuation exceeded for 0.01% of an average year may then be obtained from:

$$A_{0.01} = A_s L_s F_{0.01} \qquad (4\text{-}7)$$

Step 8 - The attenuation to be exceeded for other percentages of an average year, in the range 0.001% to 1%, may be estimated from the attenuation to be exceeded for 0.01% of an average year by using:

$$A(P) = \left[0.12\, P^{-(0.546 + 0.043 \log P)}\right] \times A_{0.01} \qquad (4\text{-}8)$$

4.2 Fedi model

The Fedi model is based on the paper by Fedi appeared on IEE publication 195, and another paper on Radio Science [1981]. By using a similar scaling approach as in CCIR model, this model requires only a single time percentage rain rate (0.01%) on the cumulative distribution function of point rain rate data as the base time percentage to determine the attenuation and extrapolate the results to other time percentages. Fedi model uses the same equation (4-1), but with different procedures to calculate the parameters of A_S, L_S, and F_P. The calculation involved following steps:

Step 1 - Evaluate the rain height H_r (km), by using following equation:

$$H_r = [5.1 - 2.15 \log (1 + 10^{(\phi-27)/25})] \; C_f \tag{4-9}$$

where ϕ is the latitude and the correction factor C_f is defined as

$$C_f = \begin{cases} 0.6 & , \quad \phi \leq 20° \\ 0.6 + 0.02(\phi - 20) & , \quad 20° < \phi \leq 40° \\ 1.0 & , \quad 40° < \phi \end{cases} \tag{4-10}$$

Step 2 - Evaluate the slant path length L_s (km):

$$L_s = 2(H_r - H_o) \Big/ \left[\left[\sin^2\theta + \frac{2(H_r - H_o)}{8500}\right]^{1/2} + \sin\theta \right] \tag{4-11}$$

Step 3 - Determine the rain rate, R(P), exceeded for 0.01% of an average year. (Same as in CCIR model, Step 5)

Step 4 - Obtain the specific attenuation, A_s, using the frequency-dependent coefficients given in equations (3-2) and (3-3), and the rainfall rate, R, determined from Step 3. (Same as in CCIR model, Step 6)

Step 5 - The rain attenuation exceeded for 0.01% time of an average year may be obtained from

$$A_{0.01} = A_s \ L_s \ F_p \tag{4-12}$$

where F_p is defined as

$$F_p = \frac{1}{(0.867 + 0.047\ L_s)} \tag{4-13}$$

Step 6 - The attenuation to exceeded for other percentages of an average year, in the range 0.001% to 1%, may be estimated from the attenuation to be exceeded for 0.01% of an average year by using:

$$A(P) = A_{0.01} \left(k_1 \ P^{(-k_2)} \right) \tag{4-14}$$

where k_1 and k_2 are given below

P%	K_1	K_2
1.	0.12	0.50
0.3	0.14	0.45
0.1	0.15	0.41
0.03	0.17	0.39
0.003	0.20	0.35
0.001	0.22	0.33

4.3 French Model

This model was submitted to an international working party (IWP5/2) under CCIR study group 5 in March 1983. The rain attenuation equation is expressed as:

$$A(P) = A_s \, L_e(P) \tag{4-15}$$

Where A_s is the specific rain attenuation (mm/hr) which has been described in CCIR model (see Section 4.1); $L_e(P)$, the effective path length in km, is an empirical function related to the time percentage (P). It is defined as:

$$L_e(P) = d \,/\, [1 + 0.025\ (\log(2/P))^{1.7}\ d^{0.9}] \tag{4-16}$$

where
$$d = \frac{5\ (\cos\phi - 0.16\ \cos 3\phi) - H_o}{\sin\theta} \tag{4-17}$$

and H_o *is the station height (km) above mean sea level;*
θ is the elevation angle in degrees;
ϕ is the station latitude in degrees;
P is the time percentage in %.

The calculation of attenuation for a specific time percentage (P) involves following steps:

Step 1 - Determine the rain rate, R(P), exceeded for P% in an average year, (with integration time of 1 min). If this information is not available, an estimate can be obtained from maps of rain climates, as given in Chapter 5.

Step 2 - Obtain the specific attenuation, $A_s = aR^b$, using the frequency-dependent coefficients given in equations (3-2) and (3-3), and the rainfall rate, R, *determined from Step 1.*

Step 3 - Evaluate the effective path length $L_e(P)$ in km by using equations (4-16) and (4-17), and derive A(P) according to equation (4-15).

4.4 Lin Model

This model (Lin [1979]) is essentially the same as the CCIR model. It requires 5-min rain-rate as input. Lin provided the justification for 5-min rain-rate as follows:

"First, in the available long-term (>20 yr) rain rate data published by the National Climatic center, the shortest rain gauge integration time is 5 min. Twenty to fifty year distributions of 5-min point rain rates for more than 200 U.S. location have already been obtained from these publications. To obtain long-term rain rate distributions with integration times shorter than 5 min will require very costly, time consuming and tedious reprocessing of a very large volume of original strip chart records of rain-falls maintained by the National Climatic Center. Furthermore, these Weather Bureau rain gauges and the associated strip chart recorders were designed to measure rainfall accumulations in 5-min intervals or longer. Attempting to estimate high rain rates in durations much shorter than 5 min from these strip charts will encounter significant uncertainty. The difficulty stems from the fact that the rain rate is the derivative of the rainfall accumulation as a function of time recorded on these strip charts on which the width of the pen trace is generally wider than a minute."

The model can be described by

$$A(f) = aR^b \; L \; K_r(R,L) \tag{4-18}$$

where a, b = power law coefficients, obtained from equations (3-2) and (3-3);

R = 5-min point rain-rate in mm/hr;

L = radio path length in km;

$K_r(R,L)$ = path reduction coefficient, is given as:

$$K_r(R,L) = 1/(1 + L\,(R-6.2)/2636) \tag{4-19}$$

Provided R > 10 mm/hr.

The calculation of attenuation for a specific time percentage (P) involves following steps:

Step 1 - Obtain coefficients a and b from equations (3-2) and (3-3).

Step 2 - Determine the rain rate, R(P), exceeded for P% in an average year. (with an integration time of 5 min.).

Step 3 - Calculate the specific attenuation, A_s, using a and b coefficients obtained from Step 1 and rainfall rate, R, determined from Step 2.

Step 4 - Evaluate the radio path length L(P) in km by using equations

$$L = \frac{H_r - H_o}{\text{SIN}\ \theta} \tag{4-20}$$

where the rain height, H_r, is defined as:

$$H_r = 5.1 - 2.15 \log \left(1 + 10^{(\phi-27)/25}\right) \tag{4-21}$$

Step 5 - Evaluate path reduction coefficient, $K_r(R,L)$, by using L and R obtained from previous steps. If 1-min point rain rate is available, then K_r is unity, and the rain attenuation can be expressed as:

$$A(f) = a(f)\ R^{b(f)}\ L \tag{4-22}$$

where R (mm/hr) is 1-min rain rate.

Step 6 - Obtain rain attenuation A(f).

4.5 Simple Attenuation Model

Based on a paper by Stutzman and Dishman [1982], the Simple Attenuation Model characterizes all path-length-dependent parameters directly in terms of point rain rate, R. It defines the attenuation as:

$$A = \begin{cases} A_s \, L_e \, ; & \text{if } R \leq 10 \text{ mm/hr} \quad (4\text{-}23a) \\[2ex] A_s \dfrac{1-\exp[k \ln (R/10) \, L_e \cos \theta \,]}{k \ln (R/10) \cos \theta} \, ; & \text{if } R > 10 \text{ mm/hr} \quad (4\text{-}23b) \end{cases}$$

where $k = a/22$ and a can be computed from Equation (3-2);

θ = elevation angle in degrees;

R = point rain rate in mm/hr at time percentage P;

L_e = effective path length in km.

The calculation of attenuation for a specific time percentage (P) involves following steps:

Step 1 - Determine the rain rate, R(P), exceeded for P% in an average year. (with an integration time of 1 min). If this information cannot be obtained from local data sources, an estimate can be obtained from maps of rain climates given in the next Chapter.

Step 2 - Obtain the specific attenuation, A_s, using the frequency-dependent coefficients given in equations (3-2) and (3-3), and the rainfall rate, R, determined from Step 1.

Step 3 - Evaluate rain height H_r in km. The effective rain height, H_r, is given by

$$H_r = \begin{cases} h_i & ; \quad R \leq 10 \text{ mm/hr} \\ h_i + \log(R/10) & ; \quad R > 10 \text{ mm/hr} \end{cases} \tag{4-24}$$

where the 0°C isotherm height, h_i, is defined in terms of latitude, in degrees by

$$h_i = \begin{cases} 4.8 & ; \quad |\phi| \leq 30° \\ 7.8 - 0.1\,|\phi| & ; \quad |\phi| > 30° \end{cases} \tag{4-25}$$

(Note that the H_r thus defined does not employ a height-reduction factor for tropical latitudes; the attenuation estimates for such area are found to be too high.)

Step 4 - Evaluate of effective path length L_e in km. The effective path length is given by

$$L_e = (H_r - H_o) \,/\, \mathrm{SIN}\ \theta \tag{4-26}$$

Where H_r is the rain height in km, obtained from Step 3;

θ is the path elevation angle in degrees;

H_o is the station height above mean sea level in km.

Step 5 - Evaluate the attenuation in dB. If rain rate is less than or equate to 10 mm/hr, equation (4-23a) is used, otherwise equation (4-23b) is used.

4.6 Other Models

4.6.1 Crane models: These models are based on papers of Crane [1980, 1982]. The behavior of these models is very similar to CCIR continental model, except more pessimistic. Calculations by Macchiarella [1982] have revealed that attenuation values according to Crane's model, either the 1980 model or the 1982 model, are overly conservertive for most conditions.

4.6.2 Misme-Waldteufel Model: This model is based on a paper by Misme and Waldteufel in 1980. The estimation procedure is basically a computer algorithm (although the physical consideration are most interesting). An alternate extension of the previous terrestrial version is not widely available.

4.6.3 Dutton-Dougherty Model: This model is based on the paper by Dutton et al [1982]. Application of this computer model appears to have been achieved only by the authors.

5. The Database

5.1 Rain Climate Zonings and Cumulative Statistics

Rainfall of high intensity is difficult to record and measure experimentally, as well as being highly variable from year to year. In radio wave propagation applications, system engineers often do not concern about the precise characteristics of rainfall as the meteorologists do, but concern only the annual cumulative statistics at a few specific percentiles, in particular, at 3%, 1%, 0.3%, 0.1%, 0.03%, 0.01%, 0.003% and 0.001%. Recognizing that the cumulative statistics at these percentages are rather superficial from climatological viewpoint, system engineers make further modeling of rain on an empirical basis by dividing the world into rain climatic zones.

Among the entire world, 14 zones are assigned as labeled from zone A to zone P (no designation for I and O). The division of zones is largely from system engineering convenience and it does not necessarily have meanings in strict meteorological sense. The latest zone division is provided by CCIR, as summarized in Figures 5-1 to 5-3, in which zone assignments for North and South America, Europe and Africa, Asia and Australia are shown, respectively.

Once zones are assigned for any part of the world, the cumulative statistics at given percentiles can be further assigned. This is shown in Table 5-1.

The above are the essential background information required to comprehend the database.

Figure 5-1 Climate Zone Assignment for North and South America

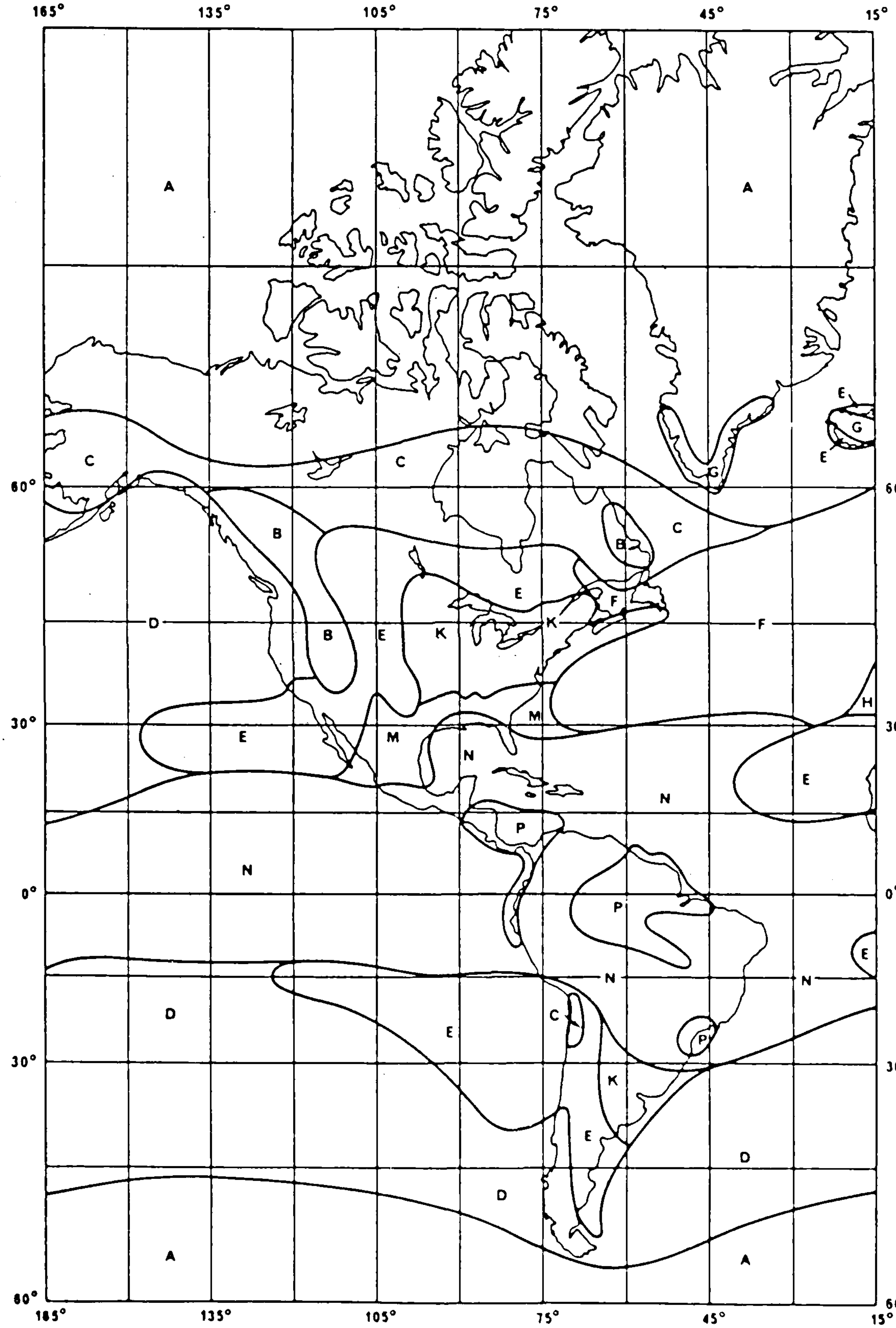


Figure 5-2 Climate Zone Assignment for Europe, Africa and Central Asia

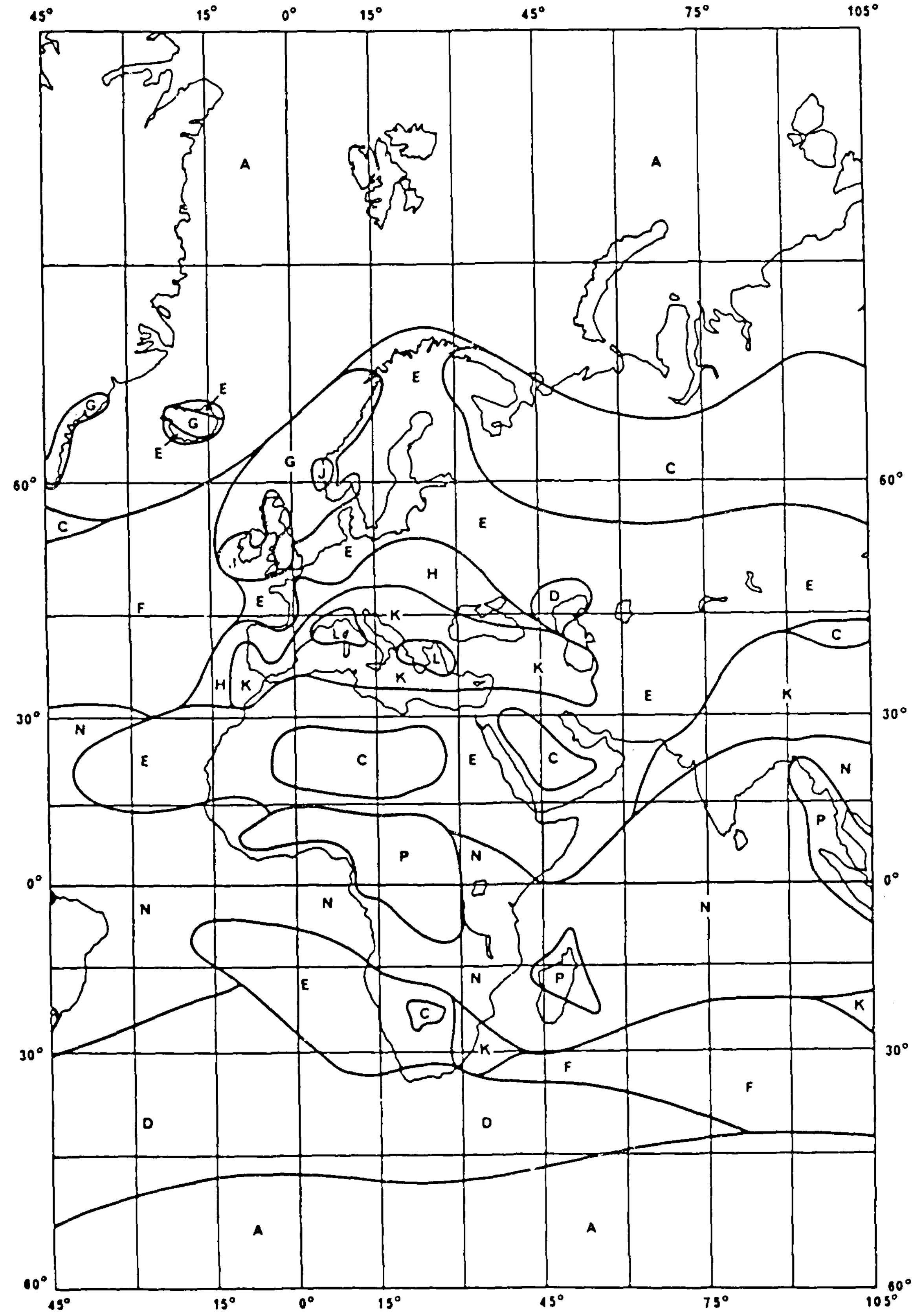


Figure 5-3 Climate Zone Assignment for Asia and Australia

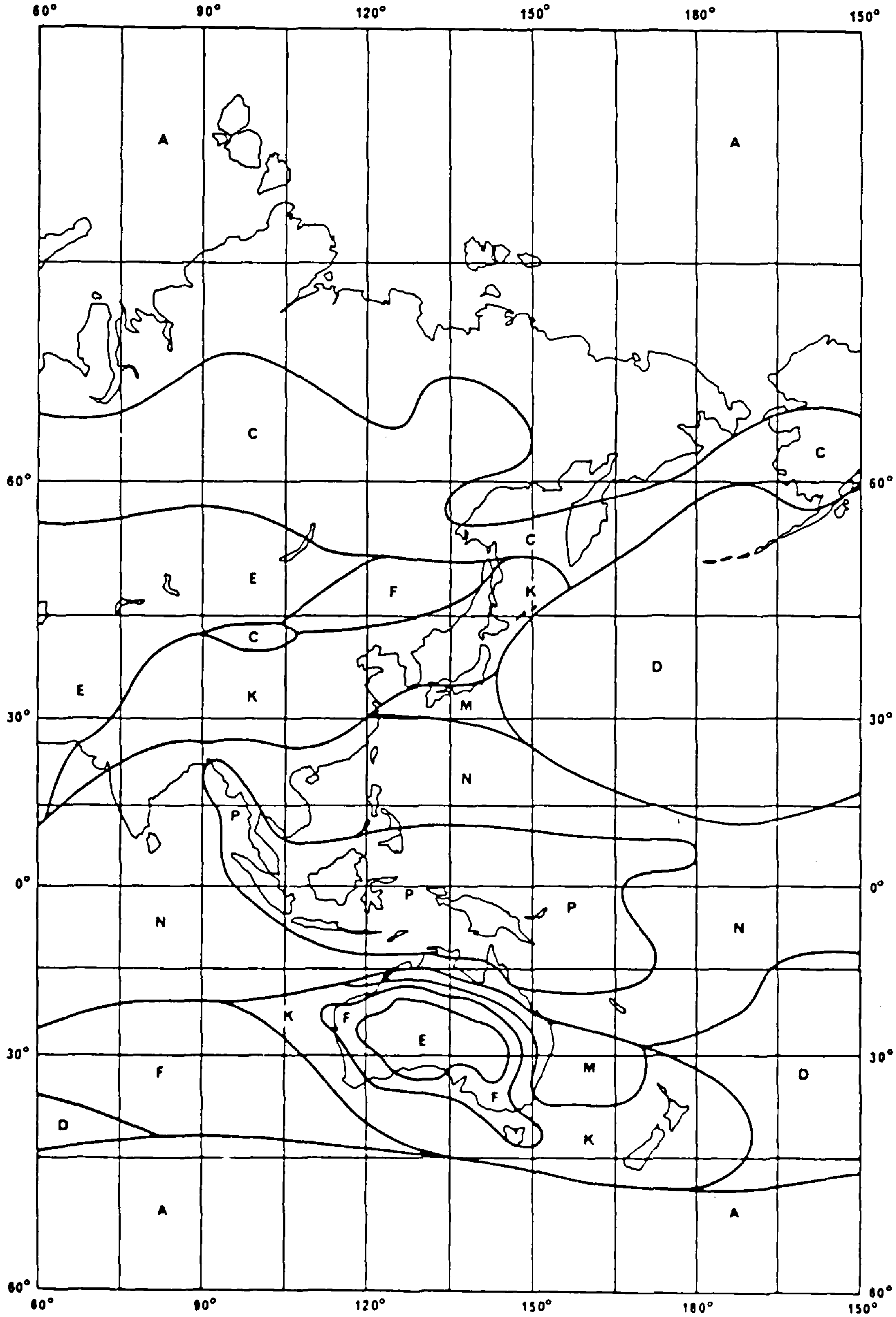


Table 5-1 - Rainfall intensity exceeded (mm/hr) at 7 Time Percentages for Various Rainfall Climatic Zones

Time (%)	A	B	C	D	E	F	G	H	J	K	L	M	N	P
1.0	.5	1	2	3	1	2	3	2	8	2	2	4	5	12
0.3	1	2	3	5	3	4	7	4	13	6	7	11	15	34
0.1	2	3	5	8	6	8	12	10	20	12	15	22	35	65
0.03	5	6	9	13	12	15	20	18	28	23	33	40	65	105
0.01	8	12	15	19	22	28	30	32	35	42	60	63	95	145
0.003	14	21	26	29	41	54	45	55	45	70	105	95	140	200
0.001	22	32	42	42	70	78	65	83	55	100	150	120	180	250

5.2 Rain-Induced Attenuation Database

One of the major contractual effort was devoted on the establishment of the database related to rain effects on radio frequency propagations. The sources of the database are from published journal articles, conference proceedings, and private company reports released to the public, etc., as summarized by CCIR. The database can be used for multiple purposes, including:

i) Evaluation of prediction methods for terrestrial line-of-sight propagation.
ii) Evaluation of prediction methods for earth-space propagation.
iii) Evaluation of prediction methods for interference or reliability over transhorizon paths.

The database, so far unavailable in any literature, either public or private, is presented here from pages 30 to 41. The database uses the following explanations:

Station:	Station Name
Lat:	Station Latitude in degrees
Long:	Station Longitude in degrees
Height:	Station Height in km above sea level
RZ:	rain climatic zone (see section II)
T:	type of measurement: B = satellite beacon R = radiometer (sky noise) S = radiometer (sun tracker)
Freq:	Frequency in GHz
Elev:	Path elevation angle in degrees
Pol:	Polarization angle in degrees from horizontal (for linear polarization) H = horizontal (nominally) V = vertical (nominally) C = circular
Time period:	period of measurement (year.month - year.month)
Duration:	in years or in months

Station Lat., Long., height	Country height	RZ	T	Freq Pol	Elev	Time period Duration	3.0	1.0	0.3	0.1	0.03	0.01	0.003	0.001
							Attenuation (dB) / Rain rate (mm/h) for time percentages of							
Waltham	USA	K	B	11.7	24.0	77.06-78.05	.	.	.	2.1	.	10.3	.	.
42.4N, 71.3W,0.00km				C		12 mo.	.	3.8	.	19.0	.	58.0	.	96.
Waltham	USA	K	B	11.7	24.0	78.06-79.05	.	.	.	1.8	.	8.2	.	15.3
42.4N, 71.3W,0.00km				C		12 mo.	.	3.7	.	16.0	.	46.0	.	86.0
Waltham	USA	K	B	19.0	35.5	78.01-78.12	.	.	.	3.0	.	28.0	.	.
42.4N, 71.3W,0.00km				H		12 mo.	.	2.8	.	14.0	.	42.0	.	90.0
Waltham	USA	K	B	19.0	38.5	79.01-79.12	.	2.1	.	7.5	.	18.7	.	.
42.4N, 71.3W,0.00km				H		12 mo.	.	3.0	.	18.0	.	53.0	.	93.0
Waltham	USA	K	B	28.6	35.5	78.01-78.12	.	.	.	7.2	.	.	.	.
42.4N, 71.3W,0.00km				V		12 mo.	.	2.8	.	14.0	.	42.0	.	90.0
Waltham	USA	K	B	28.6	38.6	79.01-79.12	.	4.0	.	18.8	.	.	.	.
42.4N, 71.3W,0.00km				V		12 mo.	.	3.0	.	18.0	.	53.0	.	93.0
Grant Park	USA	K	B	19.0	21.0	76.07-77.06	.	.	.	9.5	.	.	.	.
41.1N, 87.4W,0.10km				V		12 mo.	.	.	.	.	.	.	.	.
Grant Park	USA	K	B	19.0	41.8	77.08-78.08	.	.	.	9.0	.	.	.	.
41.1N, 87.4W,0.10km				V		12 mo.	.	.	.	.	.	.	.	.
Grant Park	USA	K	B	28.6	27.3	76.07-77.06	.	.	.	17.0	.	.	.	.
41.1N, 87.4W,0.10km				V		12 mo.	.	.	.	.	.	.	.	.
Grant Park	USA	K	B	28.6	41.8	77.08-78.08	.	.	.	20.0	.	.	.	.
41.1N, 87.4W,0.10km				V		12 mo.	.	.	.	.	.	.	.	.
Holmdel	USA	K	B	11.7	27.0	76.04-77.04	.	0.6	1.8	3.4	8.4	.	.	.
40.4N, 74.1W,0.11km				C			.	.	.	.	.	.	.	.

Holmdel	USA	K	B	11.7	27.0	77.04-78.04	.	0.6	1.8	3.0	7.3	13.5	23.7	.
40.4N, 74.1W,0.11km				C			.	.	.	.	.	.	.	.
Holmdel	USA	K	B	11.7	27.0	78.04-79.04	.	0.6	1.5	2.4	4.8	9.5	19.5	30.0
40.4N, 74.1W,0.11km				C			.	.	.	.	.	.	.	.
Holmdel	USA	K	B	19.0	18.5	76.06-78.06	1.0	2.5	5.5	12.0	25.0	>40.0	.	.
40.4N, 74.1W,0.11km				V		24 mo.	.	.	.	.	.	.	.	.
Holmdel	USA	K	B	19.0	38.6	77.05-78.05	.	2.0	3.8	6.5	13.5	22.0	44.0	.
40.4N, 74.1W,0.11km				69.		12 mo.	.	.	.	.	.	.	.	.
Holmdel	USA	K	B	19.0	38.6	77.05-78.05	.	2.0	4.0	7.0	14.5	24.0	>45.0	.
40.4N, 74.1W,0.11km				21.		12 mo.	.	.	.	.	.	.	.	.
Holmdel	USA	K	B	28.6	38.6	77.05-78.05	.	4.0	8.0	14.0	28.0	44.0	.	.
40.4N, 74.1W,0.11km				69.		12 mo.	.	.	.	.	.	.	.	.
Clarksburg	USA	K	B	19.0	21.0	76.07-77.07	.	1.1	4.5	10.0	19.0	25.0	.	.
39.2N, 77.3W,0.18km				H		12 mo.	.	2.0	6.0	12.5	31.0	67.0	.	.
Clarksburg	USA	K	B	19.0	41.0	77.08-78.08	.	.	2.5	6.0	14.0	25.0	.	.
39.2N, 77.3W,0.18km				V		12 mo.	.	2.8	6.0	11.0	25.0	50.0	.	.
Clarksburg	USA	K	B	19.0	41.0	77.08-78.08	.	0.8	3.2	7.4	17.0	27.0	.	.
39.2N, 77.3W,0.18km				H		12 mo.	.	2.8	6.0	11.0	25.0	50.0	.	.
Clarksburg	USA	K	B	19.0	43.5	78.08-80.09	.	0.8	5.0	9.8	16.0	24.0	.	.
39.2N, 77.3W,0.18km				V		24 mo.	.	2.2	6.5	17.0	40.0	70.0	.	.
Clarksburg	USA	K	B	28.6	21.0	76.07-77.07	.	3.0	7.9	15.6	27.0	.	.	.
39.2N, 77.3W,0.18km				V		12 mo.	.	2.0	6.0	12.5	30.0	67.0	.	.
Clarksburg	USA	K	B	28.6	41.0	77.08-78.08	.	1.8	6.0	13.4	24.5	.	.	.
39.2N, 77.3W,0.18km				V		12 mo.	.	2.8	6.0	11.0	25.0	50.0	.	.
Clarksburg	USA	K	B	28.6	43.5	78.08-80.08	.	4.2	10.2	17.3	27.0	.	.	.
39.2N, 77.3W,0.18km				V		24 mo.	.	2.0	6.5	17.0	40.0	70.0	.	.

Clarksburg	USA K	R	11.6	21.0	76.07-77.07	.	0.5	1.5	3.0	5.1	6.8	.	.
39.2N, 77.3W,0.18km			H		12 mo.	.	2.0	6.0	12.5	30.0	67.0	.	.
Clarksburg	USA K	R	11.6	41.0	77.08-78.08	.	0.3	1.0	2.3	4.1	8.5	.	.
39.2N, 77.3W,0.18km			H		12 mo.	.	2.8	6.0	11.0	25.0	50.0	.	.
Clarksburg	USA K	R	11.6	42.0	74.10-75.09	.	.	2.4	3.8	6.3	10.2	.	.
39.2N, 77.3W,0.18km			H		12 mo.	.	.	6.0	16.0	39.0	80.0	.	.
Clarksburg	USA K	R	11.6	43.5	78.08-79.08	.	0.2	1.0	2.5	6.0	8.9	.	.
39.2N, 77.3W,0.18km			H		12 mo.	.	2.5	6.0	16.0	42.0	69.0	.	.
Clarksburg	USA K	B	19.0	21.0	76.07-77.07	.	1.0	3.8	8.6	16.0	22.2	.	.
39.2N, 77.3W,0.18km			V		12 mo.	.	2.0	6.0	12.5	30.0	67.0	.	.
Greenbelt	USA K	B	11.7	29.0	76.07-77.06	.	0.3	1.0	1.8	4.6	8.9	17.0	.
38.5N, 77.0W,0.20km			C		12 mo.	.	3.0	8.0	19.0	35.0	63.0	94.0	133.0
Greenbelt	USA K	B	11.7	29.0	77.07-78.06	.	0.5	1.2	2.2	5.1	12.1	20.3	26.3
38.5N, 77.0W,0.20km			C		12 mo.	.	3.0	7.0	14.0	30.0	60.0	96.0	130.0
Greenbelt	USA K	B	11.7	29.0	78.07-79.06	.	0.6	1.1	1.7	5.9	14.0	26.0	29.4
38.5N, 77.0W,0.20km			C		12 mo.	.	3.0	7.0	14.0	30.0	50.0	90.0	120.0
Greenbelt	USA K	B	11.7	29.0	76.07-79.06	.	0.5	1.1	1.8	5.0	11.9	21.0	27.8
38.5N, 77.0W,0.20km			C		36 mo.	.	4.0	7.0	15.0	32.0	60.0	94.0	124.0
Wallops Island	USA K	B	28.6	41.6	77.04-78.03	.	2.2	6.3	13.0	.	.	.	.
37.8N, 75.5W,0.00km			V		12 mo.	.	1.8	6.8	14.0	36.0	70.6	.	.
Wallops Island	USA K	B	28.6	44.5	78.09-79.08	.	2.9	7.5	15.5	.	.	.	.
37.8N, 75.5W,0.00km			V		12 mo.	.	3.8	9.4	19.8	38.0	65.0	.	.
Wallops Island	USA K	B	28.6	44.5	79.09-80.08	.	3.3	8.1	17.7	.	.	.	.
37.8N, 75.5W,0.00km			V		12 mo.	.	2.4	6.2	14.3	32.2	57.7	.	.
Blacksburg	USA K	B	11.7	33.0	77.01-77.11	.	1.1	3.0	4.0	8.0	13.0	19.0	24.0
37.2N, 80.5W,0.64km			C		11 mo.	.	1.0	4.0	10.0	37.0	54.0	86.0	106.0

Blacksburg	USA	K	B	11.7	33.0	78.01-78.12	.	2.0	.	3.7	.	6.0	11.0	13.0
37.2N, 80.5W,0.64km				C		12 mo.	.	0.1	.	7.0	.	32.0	78.0	99.0
Blacksburg	USA	K	B	11.7	33.0	76.06-79.06	.	0.7	2.7	3.7	6.3	10.3	16.0	23.1
37.2N, 80.5W,0.64km				C		31 mo.	.	1.1	5.0	12.0	27.0	51.0	87.0	125.0
Blacksburg	USA	K	B	19.0	46.0	79.01-79.11	.	.	.	5.0	11.0	14.0	23.0	26.0
37.2N, 80.5W,0.64km				52.5		11 mo.	.	.	.	9.0	19.0	38.0	61.0	104.0
Blacksburg	USA	K	B	19.0	46.0	79.01-79.11	.	.	5.0	8.0	12.0	16.0	26.0	.
37.2N, 80.5W,0.64km				37.2		11 mo.	.	.	5.0	8.0	18.0	37.0	61.0	.
Blacksburg	USA	K	B	19.0	45.0	77.06-80.08	.	2.0	3.4	5.1	10.0	16.9	23.8	.
37.2N, 80.5W,0.64km				52.5		32 mo.	.	1.0	4.0	8.0	21.0	43.0	74.0	104.0
Blacksburg	USA	K	B	19.0	45.0	78.07-80.08	.	3.1	5.0	6.0	11.0	19.0	26.0	30.0
37.2N, 80.5W,0.64km				37.2		32 mo.	.	1.0	4.0	8.0	21.0	43.0	74.0	104.0
Blacksburg	USA	K	B	28.6	45.0	77.05-81.08	.	5.5	8.3	12.1	19.7	27.7	.	.
37.2N, 80.5W,0.64km				52.5		40 mo.	.	1.0	4.0	8.0	24.0	49.0	.	.
Blacksburg	USA	K	B	11.6	10.7	79.01-79-12	.	.	4.0	6.0	10.0	16.0	20.0	22.0
37.2N, 80.5W,0.64km				C		12 mo.	.	.	.	.	17.0	35.0	60.0	100.0
Blacksburg	USA	K	B	11.6	10.7	80.01-80.12	.	.	4.0	6.0	11.0	16.0	20.0	24.0
37.2N, 80.5W,0.64km				C		12 mo.	.	.	.	10.0	25.0	45.0	80.0	>100.0
Blacksburg	USA	K	B	11.6	10.7	81.01-81.12	.	.	.	7.0	13.0	19.0	22.0	24.0
37.2N, 80.5W,0.64km				C		12 mo.	.	.	.	.	25.0	55.0	80.0	95.0
Blacksburg	USA	K	B	11.6	10.7	79.01-81.12	.	.	3.8	6.6	12.0	16.9	21.3	23.2
37.2N, 80.5W,0.64km				C		36 mo.	.	.	3.0	8.0	21.0	46.0	77.0	102.0
Palmetto	USA	M	B	19.0	29.9	76.06-77.07	.	.	.	10.0	.	.	.	.
33.3N, 84.4W,0.10km				V		12 mo.	.	.	.	.	.	.	.	.
Palmetto	USA	M	B	19.0	49.5	77.08-78.08	.	.	.	9.0	.	.	.	.
33.3N, 84.4W,0.10km				V		12 mo.	.	.	.	.	.	.	.	.

Palmetto	USA	M	B	28.6	29.9	76.06-77.07	.	.	.	20.0	.	.	.	.
33.3N, 84.4W,0.10km				V		12 mo.	.	.	.	.	.	.	.	.
Palmetto	USA	M	B	28.6	49.5	77.08-78.08	.	.	.	18.0	.	.	.	.
33.3N, 84.4W,0.10km				V		12 mo.	.	.	.	.	.	.	.	.
Austin	USA	M	B	11.7	50.0	76.06-77.06	.	.	1.3	2.2	5.2	8.7	17.5	.
30.4N, 97.7W,0.24km				C		12 mo.	.	.	<5.	10.0	28.0	47.0	67.0	93.0
Austin	USA	M	B	11.7	50.0	77.06-78.06	.	.	1.0	2.7	9.5	20.5	.	.
30.4N, 97.7W,0.24km				C		12 mo.	.	.	<5.0	10.0	36.0	67.0	97.0	120.0
Austin	USA	M	B	11.7	50.0	78.06-79.06	.	.	1.2	2.9	7.0	11.4	16.5	19.1
30.4N, 97.7W,0.24km				C		12 mo.	.	.	5.0	16.0	35.0	54.0	85.0	116.0
Austin	USA	M	R	13.6	52.0	78.10-80.11	.	0.6	1.5	3.8	10.0	.	.	.
30.4N, 97.7W,0.24km				V		26 mo.	.	8.0	.	15.0	.	54.0	.	92.0
Austin	USA	M	B	19.0	52.0	78.10-80.08	.	<1.0	2.6	6.8	16.6	23.9	30.0	.
30.4N, 97.7W,0.24km				V		22 mo.	.	9.0	10.0	18.0	35.0	57.0	78.0	95.0
Austin	USA	M	R	28.6	52.0	78.10-80.08	<1.0	1.8	5.8	15.5	33.4	.	.	.
30.4N, 97.7W,0.24km				V		22 mo.	.	9.0	10.0	18.0	35.0	57.0	78.0	95.0
Tampa	USA	N	B	19.0	54.5	79.01-79.12	.	.	.	21.0	.	.	.	.
27.6N, 82.3W,0.00km				V		12 mo.	.	.	.	.	.	.	.	.
Tampa	USA	N	B	19.0	54.5	79.01-79.12	.	1.0	.	30.0	.	.	.	.
27.6N, 82.3W,0.00km				H		12 mo.	.	.	.	.	.	.	.	.
Lenox	USA	K	R	11.6	18.0	77.10-78.10	0.5	1.2	2.4	4.8	9.4	.	.	.
39.6N, 79.3W,0.61km				H		12 mo.	.	.	.	.	.	.	.	.
Etam	USA	K	R	11.6	18.0	77.10-78.10	0.5	1.4	2.8	5.8	11.5	.	.	.
39.3N, 79.7W,0.56km				H		12 mo.	.	.	.	.	.	.	.	.
Utibe	PNR	P	R	15.3	55.0	71.09-72.06	.	1.6	.	10.0	.	.	.	.
9.1N, 79.3W,				H			.	.	.	.	.	.	.	.

Manaus	B	P	R	11.7	55.0	73.12-74.04	.	2.0	.	12.5	.	.	.	.
3.1S, 60.3W,				H			.	.	.	.	.	.	.	.
Trondheim	NOR	G	B	11.6	18.0	79.05-79.07	.	0.9	.	2.0	.	4.1	.	.
63.6N, 10.4E,				H			.	.	.	.	.	.	.	.
Bergen	NOR	J	B	11.6	21.0	79.05-79.09	.	1.7	.	3.4	.	6.4	.	10.1
60.4N, 5.3E,				H			.	.	.	.	.	.	.	.
Kjeller	NOR	J	B	11.6	22.0	80.05-80.09	.	0.8	.	2.1	.	6.9	.	12.6
60.0N, 11.0E,				H			.	3.0	.	15.0	.	40.0	.	75.0
Eik	NOR	G	B	11.6	23.0	80.04-80.06	.	1.0	.	2.0	.	4.2	.	.
61.3N, 5.2E,0.00km				H			.	.	.	.	.	.	.	.
Albertslund	DNK	E	B	11.8	26.5	79.01-80.12	.	.	.	.	1.4	2.3	4.5	7.8
55.7N, 12.4E,0.00km				C		2 yr.	.	.	.	.	9.0	16.0	33.0	53.0
Albertslund	DNK	E	B	14.5	26.5	79.01-79.12	.	.	.	1.2	2.5	4.1	6.2	8.0
55.7N, 12.4E,0.00km				C		1 yr.	.	.	.	.	8.0	14.0	32.0	45.0
Albertslund	DNK	E	B	11.8	26.5	79.12-81.12	.	.	.	.	1.7	2.8	4.9	7.9
55.7N, 12.4E,0.00km				C		3 yr.	.	.	.	.	.	.	.	.
Albertslund	DNK	E	B	14.5	26.5	79.01-81.12	.	.	.	1.3	2.6	3.8	5.4	7.0
55.7N, 12.4E,0.00km				C		3 yr.	.	.	.	.	.	.	.	.
Martlesham	G	E	B	11.6	29.9	79.01-81.12	.	.	.	1.4	2.6	3.8	5.7	8.0
52.1N, 1.3E,0.03km				H		3 yr.	.	.	.	.	.	17.0	32.0	48.0
Martlesham	G	E	B	14.5	29.9	79.01-81.12	.	.	.	1.3	2.4	3.6	5.4	7.9
52.1N, 1.3E,0.03km				C		3 yr.	.	.	.	.	.	17.0	32.0	48.0
Martlesham	G	E	B	14.5	29.9	79.01-81.12	.	.	.	1.8	3.5	5.5	8.1	11.6
52.1N, 1.3E,0.03km				C		3yr.	.	.	.	.	.	17.0	32.0	48.0
Nederhorst	HOL	E	B	11.6	27.5	79.01-81.12	.	.	.	1.6	2.6	4.7	7.5	9.9
52.2N, 5.1E,0.01km				H		3 yr.	.	.	.	8.0	17.2	30.0	47.0	66.0

Slough	G	E	B	11.8	30.3	78.07-80.08	.	.	.	<3.0	.	4.3	.	16.0
51.5N,	0.5W,0.03km		C				.	.	.	.	.	.	.	.
Slough	G	E	B	11.6	29.5	77.09-80.08	.	.	.	<3.0	.	3.0	.	9.0
51.5N,	0.5W,0.03km		H				.	.	.	.	.	.	.	.
Leeheim	D	E	B	11.8	32.9	79.01-79.12	.	.	.	1.2	2.6	6.0	10.3	14.8
49.9N,	8.4E,0.09km		C				.	1.4	3.3	6.7	15.0	32.9	50.7	68.6
Leeheim	D	E	R	11.8	32.9	80.01-80.12	.	.	.	0.9	2.2	5.3	10.7	13.2
49.9N,	8.4E,0.09km		C				.	1.4	3.1	5.5	11.0	24.3	35.7	50.0
Leeheim	D	E	B	11.8	32.9	81.01-81-12	.	.	.	1.4	3.1	7.8	14.7	21.1
49.9N,	8.4E,0.09km		C				.	1.8	3.9	7.4	17.6	33.0	66.1	83.0
Leeheim	D	E	R	11.0	27.0		.	.	.	.	3.1	5.5	8.7	.
49.9N,	8.4E,0.09km						.	.	.	.	.	.	.	.
Gometz	F	H	B	11.6	32.0	78.01-78.12	.	1.0	1.6	2.4	3.4	4.7	6.4	7.8
48.7N,	2.1E,0.17km		C			1 yr.	.	.	.	6.0	12.0	20.0	28.5	39.0
Gometz	F	H	B	11.6	32.0	79.01-79.12	.	.	1.3	2.2	3.3	4.7	7.3	9.3
48.7N,	2.1E,0.17km		H			1 yr.	.	.	4.0	6.0	11.5	21.0	35.0	54.0
Gometz	F	H	B	14.5	33.6	79.01-79.12	.	1.0	1.6	2.4	3.8	5.4	7.9	10.4
48.7N,	2.1E,0.17km		C			1 yr.	.	.	4.0	6.0	11.5	21.0	35.0	54.0
Gometz	F	H	B	11.8	33.6	79.01-79.11	.	1.6	2.6	3.7	5.2	7.0	10.9	15.0
48.7N,	2.1E,0.17km		C			1 yr.	.	.	4.0	6.0	11.5	21.0	35.0	54.0
Munich	D	K	B	11.6	29.0	79.01-79.12	.	<1.0	.	1.0	.	5.0	.	13.0
48.2N,	11.6E,0.51km		H			12 mo.	.	.	.	.	.	.	.	.
Lario	I	K	B	11.6	32.0	78.01-82.12	.	.	1.5	2.9	6.5	11.5	.	.
46.2N,	9.4E,0.21km		C			5 yr.	.	3.2	7.0	12.5	27.8	52.0	84.0	117.0
Lario	I	K	B	17.8	32.0	78.01-82.12	.	.	3.5	6.4	14.0	23.9	.	.
46.2N,	9.4E,0.21km		C			5 yr.	.	3.2	7.0	12.5	27.8	52.0	84.0	117.0

Spino d'Adda	I	K	B	11.6	32.0	80.01-82.12	.	.	.	2.6	6.5	14.0	22.7	.
45.4N, 9.5E,0.08km				V		3 yr.	.	.	5.0	9.9	27.0	55.0	92.5	126.0
Fucino	I	K	B	11.6	31.0	78.01-82.12	.	.	1.2	1.9	3.0	4.9	9.0	12.9
42.0N, 13.6E,0.68km				C		60 mo.	.	2.4	5.0	8.5	15.0	26.0	46.0	69.0
Fucino	I	K	B	17.8	31.0	78.01-82.12	.	.	2.8	4.3	6.8	10.6	18.8	26.7
42.0N, 13.6E,0.68km				C		60 mo.	.	2.4	5.0	8.5	15.0	26.0	46.0	69.0
Sodankyla	FNL	E	B	11.6	13.2	79.01-83.12	.	.	.	1.8	2.9	4.5	6.5	.
67.4N, 26.6E,0.18km				H		5 yr.	.	.	.	4.3	7.8	13.3	26.0	34.8
Kirkkonummi	FNL	E	B	11.8	20.6	79.01-80.12	.	.	.	1.4	2.6	4.6	6.7	8.3
60.2N, 24.4E,0.06km				C		2 yr.	.	.	.	6.4	13.0	23.0	37.9	64.0
Stockholm	S	E	B	11.6	22.4	79.01-79.12	.	.	.	0.7	1.8	3.9	6.6	9.3
59.3N, 18.1E,0.06km				H		1 yr.	.	.	.	5.0	10.1	22.0	35.5	46.0
Stockholm	S	E	B	14.5	22.4	79.01-79.12	.	.	.	1.2	2.5	5.0	8.7	11.4
59.3N, 18.1E,0.06km				C		1 yr.	.	.	.	5.0	10.1	22.0	35.5	46.0
Lustbuehel	AUT	K	B	11.6	35.2	79.01-82.12	.	.	2.6	3.4	5.5	7.0	15.9	.
47.1N, 15.5E,0.49km				H		4 yr.	.	.	.	23.0	45.0	70.0	99.0	128.0
Lyngby	DNK	E	B	11.8	26.5	80.01-81.12	.	.	1.4	2.1	2.9	3.5	4.2	5.4
55.7N, 12.4E,0.03km				C		2 yr.	.	.	.	.	.	.	.	.
Delhi	IND	K	S	11.0		77.06-78.04	.	1.0	.	4.0	.	10.0	.	14.0
28.4N, 77.1E,0.24km							.	10.0	.	40.0	.	100.0	.	140.0
Wakkanai	J	K	B	12.1	29.1		.	<1.0	.	1.7	.	2.9	.	8.0
45.4N,141.7E,0.06km				V		1 yr.	.	2.5	.	9.9	.	20.3	.	52.1
Wakkanai	J	K	B	19.5	37.0		.	<1.0	.	2.9	.	8.4	.	14.3
45.4N,141.7E,0.06km				C		1 yr.	.	2.5	.	10.0	.	28.4	.	.
Sendai	J	K	B	19.5	45.0	79.04-80.03	.	3.0	.	6.0	.	18.0	.	.
38.2N,140.5E,0.06km				C			.	4.0	.	12.0	.	38.0	.	.

Mitaka	J	K	S	17.0	45.0			.	.	.	3.3	.	12.8	.	.
35.7N,139.6E,								.	.	.	.	.	.	.	.
Kashima	J	K	B	11.7	37.0	79.01-81.12		.	1.0	.	2.0	.	6.0	.	>10.0
35.6N,140.7E,0.04km								.	5.0	.	16.0	.	45.0	.	>80.0
Kashima	J	K	B	11.5	47.0	77.05-78.04		.	<1.0	.	2.5	.	6.2	.	.
35.6N,140.7E,0.04km								.	5.0	.	18.0	.	.	.	.
Kashima	J	K	B	19.5	48.0	78.04-82.03		.	2.0	.	6.0	.	16.0	.	31.0
36.0N,140.7E,0.04km				C				.	4.0	.	15.0	.	40.0	.	80.0
Kashima	J	K	B	34.5	47.0	77.05-78.04		.	5.0	.	19.5	.	.	.	.
36.0N,140.7E,0.04km								.	5.0	.	18.0	.	.	.	.
Setagaya	J	K	S	11.8	45.0			.	.	.	1.9	.	7.3	.	.
35.5N,139.0E,								.	.	.	.	.	.	.	.
Matsue	J	K	B	12.1	42.0			.	1.3	.	4.3	.	13.3	.	.
35.5N,133.0E,0.02km				V			1 yr.	.	4.7	.	21.8	.	54.0	.	87.5
Yokohama	J	K	B	19.5	48.0	78.04-80.03		.	4.0	.	8.0	.	16.0	.	.
35.2N,139.4E,0.02km				C				.	5.0	.	17.0	.	49.0	.	.
Yokosuka	J	M	B	19.5	48.0	78.04-80.03		.	3.0	.	7.0	.	27.0	.	.
35.1N,139.4E,0.11km				C				.	5.0	.	16.0	.	57.0	.	.
Toyokawa	J	K	S	9.4	45.0	68.01-69.12		.	1.0	.	1.8	.	4.2	.	.
34.9N,137.4E,0.01km								.	.	.	.	.	.	.	.
Osaka	J	K	B	12.1	41.0			.	1.7	.	5.6	.	15.1	.	.
34.7N,135.5E,0.04km				V			1 yr.	.	5.1	.	26.0	.	57.3	.	85.5
Marugame	J	M	R	11.9	6.0	79.05-80.04		.	2.9	.	8.7	.	.	.	.
34.3N,133.7E,0.01km				V				.	3.0	.	15.0	.	53.0	.	.
Marugame	J	M	R	11.9	15.0	79.05-80.04		.	1.7	.	5.7	.	11.8	.	.
34.3N,133.7E,0.01km				V				.	3.0	.	15.0	.	53.0	.	.

Marugame	J	M	R	11.9	45.0	79.05-80.04	.	1.3	.	3.0	.	5.7	.	.
34.3N,133.7E,0.01km				V			.	3.0	.	15.0	.	53.0	.	.
Izuhara	J	K	B	12.1	45.2		.	0.7	.	2.1	.	4.9	.	8.6
34.2N,129.3E,0.43km				V		1 yr.	.	6.2	.	22.0	.	47.3	.	76.3
Owase	J	M	B	12.1	41.5		.	1.6	.	11.5	.	>20.0	.	.
34.3N,136.2E,0.01km				V		1 yr.	.	13.3	.	61.0	.	.	.	.
Ashizuri	J	M	B	12.1	44.6		.	1.9	.	5.0	.	10.2	.	13.6
32.8N,132.9E,0.10km				V		1 yr.	.	7.3	.	31.0	.	71.1	.	107.7
Kesennuma	J	K	B	12.1	34.4		.	0.8	.	2.4	.	5.9	.	10.6
38.8N,141.5E,0.01km				V		1 yr.	.	3.6	.	12.9	.	33.7	.	71.6
Yamagawa	J	M	B	12.1	47.3	79.07-80.06	.	1.0	.	3.0	.	8.0	.	.
31.2N,130.6E,0.08km				V		1 yr.	.	7.0	.	39.0	.	>50.0	.	.
Yamagawa	J	M	B	19.5	53.0		.	2.0	.	10.0	.	17.0	.	.
31.2N,130.6E,0.08km				C		1 yr.	.	7.0	.	34.0	.	>50.0	.	.
Ogasawara	J	M	B	12.1	42.5		.	1.0	.	3.1	.	7.9	.	11.0
27.1N,142.2E,0.05km				V		1 yr.	.	3.6	.	22.6	.	67.7	.	118.7
Minamidaito	J	N	B	12.1	51.7		.	1.4	.	6.0	.	16.7	.	>20.0
25.8N,131.2E,0.19km				V		1 yr.	.	3.1	.	22.9	.	75.7	.	113.2
Taipei		N	R	11.6	20.0		.	2.2	.	8.5	.	.	.	.
25.1N,121.6E,				H			.	15.0	.	43.0	.	80.0	.	.
Yonaguni	J	N	B	12.1	57.9		.	2.7	.	8.1	.	14.3	.	16.7
24.5N,122.4E,0.20km				V		1 yr.	.	5.6	.	37.8	.	82.8	.	117.1
Klang	MLA	P	S	11.8	45.0	70.11-72.10	.	<1.0	.	6.0	.	20.0	.	.
3.1N,101.4E,0.00km							.	3.0	.	63.0	.	.	.	.
Singapore	SNG	P	R	11.6	41.0		.	1.2	.	3.9	.	>12.0	.	.
1.3N,103.9E,				H			.	3.5	.	57.0	.	124.0	.	.

Hong Kong		N	R	11.6	20.0		.	0.6	.	3.3	.	12.0	.	.
22.2N,114.2E,			H				.	3.0	.	32.0	.	88.0	.	.
Djahluhur	INS	P	B	4/6	38.0	80.10-81.09	.	0.4	1.6	2.8	3.7	4.5	5.0	5.8
6.5S,107.4E,0.70km			C				.	.	22.9	51.0	79.2	109.2	138.5	162.8
Darwin	AUS	NP	R	11.1	60.0	77.11-79.04	.	0.8	2.9	5.8	9.2	12.3	.	.
12.5S,130.9E,0.02km			V					7.0	27.0	71.0	115.0	156.0	197.00	236.0
Darwin	AUS	NP	R	14.2	60.0	77.11-79.04	.	1.4	4.3	9.7	.	.	.	.
12.5S,130.9E,0.02km			V					7.0	27.0	71.0	115.0	156.0	197.00	236.0
Darwin	AUS	NP	R	11.1	60.0	77.11-79.11	.	0.4	2.0	4.8	8.3	11.4	.	.
12.5S,130.9E,0.02km			V			2 yr.	.	5.0	24.0	49.0	86.0	130.0	178.0	215.0
Darwin	AUS	NP	R	14.2	60.0	77.11-79.11	.	0.9	3.4	7.6	.	.	.	.
12.5S,130.9E,0.02km			V			2 yr.	.	3.0	24.0	49.0	86.0	130.0	178.0	215.0
Innisfail	AUS	N	S	11.	30.0	74.12-76.10	.	1.6	3.5	6.3	10.2	.	.	.
17.6S,146.1E,0.01km			V				.	21.0	41.0	70.0	107.0	142.0	189.0	229.0
Innisfail	AUS	N	S	11.	45.0	76.11-79.04	.	1.6	2.5	6.4	9.8	.	.	.
17.6S,146.1E,0.01km			V				.	25.0	57.0	89.0	121.0	149.0	180.0	203.0
Clayton	AUS	F	R	11.1	45.0	80.06-83.06	.	.	.	1.0	2.1	4.3	7.7	10.3
37.9S,145.1E,0.07km			V				.	.	6.0	16.0	36.0	53.0	82.0	113.0
Clayton	AUS	F	R	14.2	45.0	80.06-83.06	.	.	0.9	1.7	3.4	6.4	10.7	.
37.9S,145.1E,0.07km			V				.	.	7.0	16.5	35.5	54.0	82.5	111.5
Clayton	AUS	F	R	11.1	15.0	80.06-83.06	.	.	1.0	1.8	3.2	5.2	9.3	10.8
37.9S,145.1E,0.07km			V				.	3.0	8.5	17.0	32.5	52.0	79.0	102.0
Mill Village NS	CAN	D	R	13.0	20.0	73.06-79.06	.	1.4	2.7	4.7	8.2	>10.0	>10.0	>10.0
44.3N, 64.3W,0.01km			H			60 mo.	.	.	.	.	.	.	.	.
Ottawa On.	CAN	D	R	13.0	26.0	73.12-75.11	.	<1.0	1.2	2.2	5.5	>10.0	>10.0	>10.0
45.2N, 75.5W,0.07km			H			24 mo.	.	.	.	.	.	.	.	.

Allan Park, On.	CAN	D	R	13.0	29.0	73.09-75.09	.	<1.0	1.7	3.3	7.5	>10.0	>10.0	>10.0
44.1N, 80.6W,0.29km			H			24 mo.	.	.	.	.	.	.	.	.
Thunder Bay On.	CAN	D	R	13.0	30.0	73.06-76.08	.	<1.0	1.3	2.5	5.2	>10.0	>10.0	>10.0
48.3N, 89.3W,0.27km			H			37 mo.	.	.	.	.	.	.	.	.
Melville, Sask	CAN	D	R	13.0	31.0	74.01-77.05	.	<1.0	1.2	2.1	3.4	5.9	>10.0	>10.0
50.6N,102.5W,0.66km			H			40 mo.	.	.	.	.	.	.	.	.
Lk.Cowichan, BC	CAN	D	R	13.0	33.0	73.10-77.02	.	<1.0	1.4	1.8	2.3	2.9	3.4	3.8
48.5N,124.0W,0.26km			H			40 mo.	.	.	.	.	.	.	.	.
Yawaguchi	J	N	R	11.9	9.2	79.10-80.09	2.1	4.6	8.5	12.1	.	.	.	.
34.1N,131.3E,0.12km			V			12 mo.	.	.	10.1	21.0	37.0	57.0	.	.
Hawada	J	N	R	11.9	8.4	79.10-80.09	1.9	4.0	7.1	10.2	.	.	.	.
34.5N,132.1E,0.22km			V			12 mo.	.	.	.	.	.	.	.	.
Mt. Fuji	J	N	R	35.3	41/20	75.07-75.12	2.0	4.0	6.6	10.0	16.6	.	.	.
35.2N,138.4E,3.78km			V			5 mo.	6.0	20.0	26.0	40.0	.	.	.	.
Gotenba	J	N	R	35.2	15/77	75.07-75.12	4.4	8.4	15.3	21.8	.	.	.	.
35.1N,138.4E,0.72km			V			5 mo.	3.0	9.0	14.0	20.0	.	.	.	.

6. Model Comparisons

6.1 Model Comparison Table

Rain attenuation predictions were computed according to the five leading models presented in Chapter 4, namely, CCIR, FEDI, FRENCH, LIN and SAM. The climate zone rain data were used if no direct measured rain data were available. A complete list of all model predictions and actual measurements along with the station information is provided in Table 6-1.

The path data are arranged by country names, and within each country by station names in alphabetical order. The station information consists of station name, country name, location (latitude and longitude in degrees), station height in (km), frequency in (GHz), polarization in (degrees), elevation angle in (degrees), rain zone, measurement in (months). Directly measured rain rate data are used when ever available, otherwise the rain rate is inferred, as noted by an asterik (*) in the rain-rate column from the climate rain zone information given in Chapter 5.

Table 6-1 Model Comparison

STATION INFORMATION	TIME %	RAIN RATE	ATTEN (dB)	PREDICTIONS CCIR	FEDI	FRENCH	LIN	SAM
Clayton AUS	1.000	2.0*	-1.00	.96	.98	.18	.16	.17
(-37.9, 145.1) .07km	.300	6.0	-1.00	1.85	1.96	.65	.62	.67
11.1GHz; Pol 90.0°	.100	16.0	1.00	3.13	3.13	1.99	2.06	2.23
Ele 45.0°; R-Zone F	.030	36.0	2.10	5.22	5.43	4.80	5.60	5.92
TYPE(R); 36 months	.010	53.0	4.30	8.03	8.13	6.88	9.02	9.37
	.003	82.0	7.70	12.21	12.42	10.32	15.43	15.68
	.001	113.0	10.30	17.19	17.48	13.58	22.91	22.83
Clayton AUS	1.000	2.0*	-1.00	1.58	1.60	.38	.33	.36
(-37.9, 145.1) .07km	.300	7.0	.90	3.03	3.21	1.49	1.40	1.52
14.2GHz; Pol 90.0°	.100	16.5	1.70	5.13	5.14	3.64	3.77	4.08
Ele 45.0°; R-Zone F	.030	35.5	3.40	8.56	8.89	7.82	9.11	9.73
TYPE(R); 36 months	.010	54.0	6.40	13.17	13.32	11.27	14.78	15.55
	.003	82.5	10.70	20.01	20.35	16.10	24.08	24.87
	.001	111.5	-1.00	28.17	28.64	20.20	34.07	34.65
Clayton AUS	1.000	3.0	-1.00	1.77	1.81	.77	.70	.75
(-37.9, 145.1) .07km	.300	8.5	1.00	3.40	3.63	2.36	2.50	2.71
11.1GHz; Pol 90.0°	.100	17.0	1.80	5.76	5.82	4.56	5.85	5.37
Ele 15.0°; R-Zone F	.030	32.5	3.20	9.60	10.07	8.08	12.97	9.65
TYPE(R); 36 months	.010	52.0	5.20	14.77	15.09	11.76	23.10	14.75
	.003	79.0	9.30	22.45	23.06	15.95	38.60	21.57
	.001	102.0	10.80	31.60	32.45	18.26	52.83	27.28
Darwin AUS	1.000	7.0	.80	3.40	2.67	.71	.50	.82
(-12.5, 130.9) .02km	.300	27.0	2.90	6.51	5.36	3.54	2.62	4.32
11.1GHz; Pol 90.0°	.100	71.0	5.80	11.04	8.58	10.79	8.64	14.06
Ele 60.0°; R-Zone NP	.030	115.0	9.20	18.40	14.85	17.65	15.66	25.18
TYPE(R); 17 months	.010	156.0	12.30	28.31	22.25	23.19	22.81	36.33
	.003	197.0	-1.00	43.04	33.99	27.48	30.42	48.06
	.001	236.0	-1.00	60.59	47.84	30.80	38.01	59.65
Darwin AUS	1.000	7.0	1.40	5.02	3.94	1.34	.93	1.53
(-12.5, 130.9) .02km	.300	27.0	4.30	9.61	7.90	6.00	4.44	7.36
14.2GHz; Pol 90.0°	.100	71.0	9.70	16.30	12.66	16.94	13.56	22.31
Ele 60.0°; R-Zone NP	.030	115.0	-1.00	27.17	21.92	26.68	23.67	38.59
TYPE(R); 17 months	.010	156.0	-1.00	41.79	32.85	34.22	33.67	54.46
	.003	197.0	-1.00	63.53	50.18	39.83	44.09	70.84
	.001	236.0	-1.00	89.44	70.62	44.01	54.31	86.79
Darwin AUS	1.000	5.0	.40	2.71	2.13	.47	.33	.54
(-12.5, 130.9) .02km	.300	24.0	2.00	5.20	4.28	3.06	2.27	3.74
11.1GHz; Pol 90.0°	.100	49.0	4.80	8.82	6.85	6.83	5.47	8.96
Ele 60.0°; R-Zone NP	.030	86.0	8.30	14.70	11.86	12.33	10.94	17.73
TYPE(R); 24 months	.010	130.0	11.40	22.61	17.77	18.52	18.22	29.19
	.003	178.0	-1.00	34.37	27.15	24.25	26.84	42.56
	.001	215.0	-1.00	48.39	38.21	27.45	33.88	53.36
Darwin AUS	1.000	3.0	.90	4.06	3.19	.50	.35	.58
(-12.5, 130.9) .02km	.300	24.0	3.40	7.79	6.40	5.24	3.87	6.42
14.2GHz; Pol 90.0°	.100	49.0	7.60	13.20	10.26	11.04	8.84	14.61
Ele 60.0°; R-Zone NP	.030	86.0	-1.00	22.01	17.76	19.07	16.92	27.75
TYPE(R); 24 months	.010	130.0	-1.00	33.86	26.61	27.72	27.28	44.33
	.003	178.0	-1.00	51.46	40.65	35.43	39.21	63.20
	.001	215.0	-1.00	72.45	57.20	39.52	48.77	78.16

STATION INFORMATION	TIME %	RAIN RATE	ATTEN (dB)	CCIR	FEDI	FRENCH	LIN	SAM
				PREDICTIONS				
Innisfail AUS	1.000	21.0	1.60	4.15	3.41	4.48	3.06	4.59
(-17.6, 146.1) .01km	.300	41.0	3.50	7.95	6.84	9.30	6.98	9.35
11.0GHz; Pol 90.0°	.100	70.0	6.30	13.47	10.96	15.92	13.50	16.41
Ele 30.0°; R-Zone N	.030	107.0	10.20	22.45	18.97	23.07	22.78	25.61
TYPE(S); 22 months	.010	142.0	-1.00	34.54	28.43	28.26	32.29	34.44
	.003	189.0	-1.00	52.51	43.43	34.27	45.93	46.44
	.001	229.0	-1.00	73.92	61.12	37.68	58.19	56.77
Innisfail AUS	1.000	25.0	1.60	3.54	2.82	4.04	2.74	4.38
(-17.6, 146.1) .01km	.300	57.0	2.50	6.79	5.66	10.42	7.59	11.39
11.0GHz; Pol 90.0°	.100	89.0	6.40	11.51	9.07	16.45	13.16	19.00
Ele 45.0°; R-Zone N	.030	121.0	9.80	19.19	15.69	21.31	19.22	26.98
TYPE(S); 29 months	.010	149.0	-1.00	29.52	23.51	24.48	24.85	34.19
	.003	180.0	-1.00	44.87	35.92	27.06	31.39	42.38
	.001	203.0	-1.00	63.17	50.55	27.80	36.41	48.57
Lustbuehel AUT	1.000	2.0*	-1.00	1.43	1.57	.23	.18	.17
(47.1, 15.5) .49km	.300	6.0*	2.60	2.74	3.15	.83	.70	.67
11.6GHz; Pol .0°	.100	23.0	3.40	4.65	5.05	3.92	3.65	3.58
Ele 35.2°; R-Zone K	.030	45.0	5.50	7.75	8.74	7.91	8.32	8.17
TYPE(B); 48 months	.010	70.0	7.00	11.93	13.10	12.06	14.29	13.93
	.003	99.0	15.90	18.13	20.01	16.12	21.86	21.04
	.001	128.0	-1.00	25.53	28.16	19.54	29.95	28.50
Manaus B	1.000	12.0*	2.00	3.76	3.05	1.74	1.26	2.02
(-3.1, -60.3) .00km	.300	34.0*	-1.00	7.20	6.11	5.84	4.50	7.06
11.7GHz; Pol .0°	.100	65.0*	12.50	12.21	9.79	11.87	9.92	15.23
Ele 55.0°; R-Zone P	.030	105.0*	-1.00	20.34	16.95	19.15	17.81	26.79
TYPE(R); 4 months	.010	145.0*	-1.00	31.29	25.40	25.52	26.40	39.10
	.003	200.0*	-1.00	47.57	38.81	33.46	39.09	56.90
	.001	250.0*	-1.00	66.97	54.61	39.29	51.32	73.76
Allan Park, On. CAN	1.000	3.0*	1.00	.49	.53	.68	.57	.56
(44.1, -80.6) .29km	.300	5.0*	1.70	.93	1.06	1.14	1.05	1.03
13.0GHz; Pol .0°	.100	8.0*	3.30	1.58	1.69	1.78	1.84	1.80
Ele 29.0°; R-Zone D	.030	13.0*	7.50	2.63	2.93	2.75	3.28	3.20
TYPE(R); 24 months	.010	19.0*	10.00	4.05	4.39	3.76	5.16	4.96
	.003	29.0*	10.00	6.16	6.71	5.34	8.54	8.03
	.001	42.0*	10.00	8.67	9.44	7.24	13.28	12.17
Lk.Cowichan, BC CAN	1.000	3.0*	1.00	.41	.45	.58	.46	.43
(48.5,-124.0) .26km	.300	5.0*	1.40	.78	.89	.99	.84	.79
13.0GHz; Pol .0°	.100	8.0*	1.80	1.32	1.43	1.57	1.48	1.39
Ele 33.0°; R-Zone D	.030	13.0*	2.30	2.21	2.48	2.45	2.64	2.50
TYPE(R); 40 months	.010	19.0*	2.90	3.40	3.72	3.39	4.15	3.96
	.003	29.0*	3.40	5.16	5.68	4.87	6.86	6.57
	.001	42.0*	3.80	7.27	7.99	6.66	10.67	10.17
Melville, Sask CAN	1.000	3.0*	1.00	.35	.39	.54	.39	.35
(50.6,-102.5) .66km	.300	5.0*	1.20	.68	.79	.92	.72	.65
13.0GHz; Pol .0°	.100	8.0*	2.10	1.15	1.26	1.46	1.26	1.14
Ele 31.0°; R-Zone D	.030	13.0*	3.40	1.92	2.19	2.30	2.25	2.08
TYPE(R); 40 months	.010	19.0*	5.90	2.95	3.28	3.21	3.54	3.38
	.003	29.0*	10.00	4.48	5.01	4.64	5.85	5.72
	.001	42.0*	10.00	6.31	7.05	6.37	9.10	8.99

STATION INFORMATION	TIME %	RAIN RATE	ATTEN (dB)	CCIR	FEDI	FRENCH	LIN	SAM
Mill Village NS CAN	1.000	3.0*	1.40	.67	.72	1.03	.88	.87
(44.3, -64.3) .01km	.300	5.0*	2.70	1.28	1.44	1.67	1.63	1.59
13.0GHz; Pol .0°	.100	8.0*	4.70	2.17	2.30	2.50	2.85	2.79
Ele 20.0°; R-Zone D	.030	13.0*	8.20	3.62	3.98	3.69	5.09	4.82
TYPE(R); 60 months	.010	19.0*	10.00	5.57	5.97	4.88	8.00	7.17
	.003	29.0*	10.00	8.46	9.12	6.71	13.25	11.07
	.001	42.0*	10.00	11.91	12.83	8.87	20.61	16.11
Ottawa On. CAN	1.000	3.0*	1.00	.54	.59	.79	.66	.64
(45.2, -75.5) .07km	.300	5.0*	1.20	1.04	1.18	1.31	1.22	1.18
13.0GHz; Pol .0°	.100	8.0*	2.20	1.76	1.89	2.02	2.13	2.07
Ele 26.0°; R-Zone D	.030	13.0*	5.50	2.94	3.26	3.06	3.80	3.64
TYPE(R); 24 months	.010	19.0*	10.00	4.53	4.89	4.14	5.98	5.59
	.003	29.0*	10.00	6.88	7.47	5.81	9.90	8.92
	.001	42.0*	10.00	9.68	10.52	7.81	15.40	13.36
Thunder Bay On. CAN	1.000	3.0*	1.00	.44	.48	.64	.50	.47
(48.3, -89.3) .27km	.300	5.0*	1.30	.84	.96	1.08	.92	.87
13.0GHz; Pol .0°	.100	8.0*	2.50	1.42	1.54	1.69	1.62	1.52
Ele 30.0°; R-Zone D	.030	13.0*	5.20	2.37	2.66	2.62	2.89	2.73
TYPE(R); 37 months	.010	19.0*	10.00	3.64	3.99	3.60	4.54	4.31
	.003	29.0*	10.00	5.54	6.10	5.14	7.52	7.09
	.001	42.0*	10.00	7.80	8.58	6.99	11.69	10.89
Leeheim D	1.000	1.4	-1.00	.62	.68	.17	.14	.13
(49.9, 8.4) .09km	.300	3.3	-1.00	1.19	1.36	.46	.39	.36
11.8GHz; Pol 45.0°	.100	6.7	1.20	2.01	2.17	.97	.91	.85
Ele 32.9°; R-Zone E	.030	15.0	2.60	3.35	3.76	2.26	2.43	2.29
TYPE(B); 11 months	.010	32.9	6.00	5.16	5.63	5.15	6.32	5.94
	.003	50.7	10.30	7.84	8.61	7.54	10.68	9.93
	.001	68.6	14.80	11.04	12.11	9.56	15.42	14.16
Leeheim D	1.000	1.4	-1.00	.43	.47	.17	.14	.13
(49.9, 8.4) .09km	.300	3.1	-1.00	.82	.94	.42	.36	.33
11.8GHz; Pol 45.0°	.100	5.5	.90	1.39	1.50	.76	.72	.67
Ele 32.9°; R-Zone E	.030	11.0	2.20	2.32	2.60	1.55	1.67	1.55
TYPE(R); 11 months	.010	24.3	5.30	3.57	3.90	3.57	4.37	4.12
	.003	35.7	10.70	5.43	5.96	4.92	6.98	6.55
	.001	50.0	13.20	7.64	8.38	6.51	10.50	9.77
Leeheim D	1.000	1.8	-1.00	.62	.68	.24	.19	.17
(49.9, 8.4) .09km	.300	3.9	-1.00	1.19	1.36	.56	.47	.44
11.8GHz; Pol 45.0°	.100	7.4	1.40	2.02	2.18	1.10	1.03	.96
Ele 32.9°; R-Zone E	.030	17.6	3.10	3.37	3.77	2.75	2.95	2.78
TYPE(B); 11 months	.010	33.0	7.80	5.18	5.65	5.17	6.34	5.96
	.003	66.1	14.70	7.87	8.64	10.41	14.74	13.56
	.001	83.0	21.10	11.08	12.16	12.05	19.44	17.67
Leeheim D	1.000	1.0*	-1.00	.39	.43	.11	.09	.08
(49.9, 8.4) .09km	.300	3.0*	-1.00	.75	.86	.41	.35	.32
11.0GHz; Pol .0°	.100	6.0*	-1.00	1.27	1.37	.85	.83	.77
Ele 27.0°; R-Zone E	.030	12.0*	3.10	2.12	2.38	1.74	1.96	1.82
TYPE(R);	.010	22.0*	5.50	3.26	3.56	3.19	4.17	3.82
	.003	41.0*	8.70	4.96	5.44	5.91	9.05	8.01
	.001	70.0*	-1.00	6.98	7.66	9.99	17.60	14.92

STATION INFORMATION	TIME %	RAIN RATE	ATTEN (dB)	CCIR	FEDI	FRENCH	LIN	SAM
				PREDICTIONS				
Munich D	1.000	2.0*	1.00	.85	.94	.27	.21	.20
(48.2, 11.6) .51km	.300	6.0*	-1.00	1.64	1.89	.96	.81	.76
11.6GHz; Pol .0°	.100	12.0*	1.00	2.78	3.03	2.03	1.90	1.79
Ele 29.0°; R-Zone K	.030	23.0*	-1.00	4.63	5.24	3.93	4.21	4.02
TYPE(B); 12 months	.010	42.0*	5.00	7.12	7.85	7.22	8.82	8.33
	.003	70.0*	-1.00	10.83	11.99	11.67	16.50	15.23
	.001	100.0*	13.00	15.24	16.87	15.84	25.55	23.06
Albertslund DNK	1.000	1.0*	-1.00	.27	.30	.13	.10	.08
(55.7, 12.4) .00km	.300	3.0*	-1.00	.52	.59	.46	.37	.32
11.8GHz; Pol 45.0°	.100	6.0*	-1.00	.88	.95	.95	.85	.74
Ele 26.5°; R-Zone E	.030	9.0	1.40	1.46	1.64	1.34	1.39	1.21
TYPE(B); 24 months	.010	16.0	2.30	2.25	2.46	2.35	2.80	2.50
	.003	33.0	4.50	3.42	3.76	4.84	6.76	6.06
	.001	53.0	7.80	4.81	5.30	7.49	12.01	10.65
Albertslund DNK	1.000	1.0*	-1.00	.37	.40	.25	.18	.16
(55.7, 12.4) .00km	.300	3.0*	-1.00	.70	.81	.81	.65	.56
14.5GHz; Pol 45.0°	.100	6.0*	1.20	1.19	1.29	1.60	1.43	1.25
Ele 26.5°; R-Zone E	.030	8.0	2.50	1.99	2.23	1.93	2.00	1.74
TYPE(B); 12 months	.010	14.0	4.10	3.05	3.35	3.19	3.81	3.38
	.003	32.0	6.20	4.64	5.11	7.07	9.87	8.94
	.001	45.0	8.00	6.54	7.19	9.12	14.61	13.18
Albertslund DNK	1.000	1.0*	-1.00	.40	.44	.13	.10	.08
(55.7, 12.4) .00km	.300	3.0*	-1.00	.76	.87	.46	.37	.32
11.8GHz; Pol 45.0°	.100	6.0*	-1.00	1.29	1.40	.95	.85	.74
Ele 26.5°; R-Zone E	.030	12.0*	1.70	2.15	2.42	1.90	1.98	1.74
TYPE(B); 36 months	.010	22.0*	2.80	3.31	3.63	3.45	4.13	3.70
	.003	41.0*	4.90	5.03	5.54	6.30	8.79	7.86
	.001	70.0*	7.90	7.09	7.80	10.51	16.84	14.75
Albertslund DNK	1.000	1.0*	-1.00	.62	.68	.25	.18	.16
(55.7, 12.4) .00km	.300	3.0*	-1.00	1.18	1.36	.81	.65	.56
14.5GHz; Pol 45.0°	.100	6.0*	1.30	2.00	2.17	1.60	1.43	1.25
Ele 26.5°; R-Zone E	.030	12.0*	2.60	3.34	3.76	3.07	3.19	2.80
TYPE(B); 36 months	.010	22.0*	3.80	5.14	5.63	5.36	6.41	5.78
	.003	41.0*	5.40	7.81	8.60	9.41	13.13	11.86
	.001	70.0*	7.00	11.00	12.11	15.16	24.31	21.62
Lyngby DNK	1.000	1.0*	-1.00	.39	.43	.13	.10	.08
(55.7, 12.4) .03km	.300	3.0*	1.40	.75	.87	.46	.36	.31
11.8GHz; Pol 45.0°	.100	6.0*	2.10	1.28	1.39	.94	.84	.73
Ele 26.5°; R-Zone L	.030	12.0*	2.90	2.13	2.40	1.89	1.95	1.72
TYPE(B); 24 months	.010	22.0*	3.50	3.28	3.60	3.44	4.08	3.67
	.003	41.0*	4.20	4.98	5.49	6.27	8.69	7.80
	.001	70.0*	5.40	7.02	7.73	10.46	16.64	14.65
Gometz F	1.000	2.0*	1.00	.33	.36	.26	.21	.19
(48.7, 2.1) .17km	.300	4.0*	1.60	.64	.73	.56	.48	.45
11.6GHz; Pol 45.0°	.100	6.0	2.40	1.08	1.16	.82	.78	.73
Ele 32.0°; R-Zone H	.030	12.0	3.40	1.80	2.01	1.67	1.83	1.72
TYPE(B); 12 months	.010	20.0	4.70	2.76	3.02	2.73	3.41	3.23
	.003	28.5	6.40	4.20	4.61	3.64	5.25	4.95
	.001	39.0	7.80	5.91	6.49	4.68	7.70	7.20

STATION INFORMATION	TIME %	RAIN RATE	ATTEN (dB)	CCIR	FEDI	FRENCH	LIN	SAM
				PREDICTIONS				
Gometz F	1.000	2.0*	-1.00	.37	.41	.27	.21	.20
(48.7, 2.1) .17km	.300	4.0	1.30	.71	.82	.58	.50	.47
11.6GHz; Pol .0°	.100	6.0	2.20	1.21	1.31	.86	.82	.77
Ele 32.0°; R-Zone H	.030	11.5	3.30	2.02	2.26	1.67	1.83	1.72
TYPE(B); 12 months	.010	21.0	4.70	3.11	3.39	3.07	3.83	3.63
	.003	35.0	7.30	4.72	5.18	4.96	7.16	6.72
	.001	54.0	9.30	6.65	7.29	7.41	12.19	11.24
Gometz F	1.000	2.0*	1.00	.55	.60	.47	.37	.35
(48.7, 2.1) .17km	.300	4.0	1.60	1.06	1.21	.97	.83	.78
14.5GHz; Pol 45.0°	.100	6.0	2.40	1.80	1.94	1.40	1.33	1.24
Ele 33.6°; R-Zone H	.030	11.5	3.80	2.99	3.35	2.60	2.81	2.65
TYPE(B); 12 months	.010	21.0	5.40	4.60	5.03	4.57	5.62	5.38
	.003	35.0	7.90	7.00	7.68	7.14	10.12	9.69
	.001	54.0	10.40	9.85	10.81	10.34	16.67	15.82
Kirkkonummi FNL	1.000	1.0*	-1.00	.44	.48	.15	.10	.08
(60.2, 24.4) .06km	.300	3.0*	-1.00	.84	.96	.52	.39	.31
11.8GHz; Pol 45.0°	.100	6.4	1.40	1.43	1.54	1.14	.97	.78
Ele 20.6°; R-Zone E	.030	13.0	2.60	2.38	2.67	2.30	2.31	1.91
TYPE(B); 24 months	.010	23.0	4.60	3.66	3.99	3.95	4.61	3.96
	.003	37.9	6.70	5.56	6.10	6.14	8.46	7.31
	.001	64.0	8.30	7.82	8.59	10.03	15.98	13.62
Sodankyla FNL	1.000	1.0*	-1.00	.24	.26	.18	.10	.06
(67.4, 26.6) .18km	.300	3.0*	-1.00	.46	.52	.61	.40	.25
11.6GHz; Pol .0°	.100	4.3	1.80	.78	.83	.82	.62	.39
Ele 13.2°; R-Zone E	.030	7.8	2.90	1.31	1.43	1.42	1.30	.80
TYPE(B); 60 months	.010	13.3	4.50	2.01	2.15	2.31	2.49	1.70
	.003	26.0	6.50	3.06	3.28	4.40	5.68	4.48
	.001	34.8	-1.00	4.30	4.62	5.39	8.13	6.62
Martlesham G	1.000	1.0*	-1.00	.29	.32	.12	.09	.08
(52.1, 1.3) .03km	.300	3.0*	-1.00	.56	.64	.43	.36	.33
11.6GHz; Pol .0°	.100	6.0*	1.40	.95	1.03	.91	.84	.76
Ele 29.9°; R-Zone E	.030	12.0*	2.60	1.58	1.78	1.84	1.97	1.80
TYPE(B); 36 months	.010	17.0	3.80	2.43	2.66	2.46	3.02	2.78
	.003	32.0	5.70	3.70	4.07	4.61	6.56	6.02
	.001	48.0	8.00	5.21	5.72	6.62	10.78	9.77
Martlesham G	1.000	1.0*	-1.00	.45	.50	.23	.18	.16
(52.1, 1.3) .03km	.300	3.0*	-1.00	.87	.99	.76	.64	.58
14.5GHz; Pol 45.0°	.100	6.0*	1.30	1.47	1.59	1.52	1.41	1.28
Ele 29.9°; R-Zone E	.030	12.0*	2.40	2.46	2.76	2.93	3.14	2.87
TYPE(B); 36 months	.010	17.0	3.60	3.78	4.13	3.83	4.69	4.33
	.003	32.0	5.40	5.74	6.32	6.82	9.71	9.00
	.001	48.0	7.90	8.09	8.89	9.51	15.49	14.24
Martlesham G	1.000	1.0*	-1.00	.45	.50	.23	.18	.16
(52.1, 1.3) .03km	.300	3.0*	-1.00	.87	.99	.76	.64	.58
14.5GHz; Pol 45.0°	.100	6.0*	1.80	1.47	1.59	1.52	1.41	1.28
Ele 29.9°; R-Zone E	.030	12.0*	3.50	2.46	2.76	2.93	3.14	2.87
TYPE(B); 3 months	.010	17.0	5.50	3.78	4.13	3.83	4.69	4.33
	.003	32.0	8.10	5.74	6.32	6.82	9.71	9.00
	.001	48.0	11.60	8.09	8.89	9.51	15.49	14.24

STATION INFORMATION	TIME %	RAIN RATE	ATTEN (dB)	PREDICTIONS				
				CCIR	FEDI	FRENCH	LIN	SAM
Slough G	1.000	1.0*	-1.00	.39	.43	.12	.10	.09
(51.5, -.5) .03km	.300	3.0*	-1.00	.76	.87	.43	.36	.33
11.8GHz; Pol 45.0°	.100	6.0*	3.00	1.28	1.39	.90	.84	.77
Ele 30.3°; R-Zone E	.030	12.0*	-1.00	2.14	2.40	1.81	1.95	1.80
TYPE(B); 25 months	.010	22.0*	4.30	3.29	3.60	3.31	4.08	3.78
	.003	41.0*	-1.00	5.00	5.49	6.07	8.69	7.95
	.001	70.0*	16.00	7.04	7.73	10.16	16.65	14.86
Slough G	1.000	1.0*	-1.00	.41	.45	.13	.10	.09
(51.5, -.5) .03km	.300	3.0*	-1.00	.79	.90	.44	.37	.34
11.6GHz; Pol .0°	.100	6.0*	3.00	1.33	1.44	.92	.87	.79
Ele 29.5°; R-Zone E	.030	12.0*	-1.00	2.22	2.49	1.87	2.03	1.86
TYPE(B); 35 months	.010	22.0*	3.00	3.42	3.74	3.43	4.26	3.93
	.003	41.0*	-1.00	5.19	5.71	6.32	9.15	8.30
	.001	70.0*	9.00	7.31	8.03	10.63	17.63	15.55
Hong Kong HK	1.000	3.0	.60	3.82	3.32	.78	.56	.90
(22.2, 114.2) .00km	.300	15.0*	-1.00	7.32	6.65	4.95	4.03	5.78
11.6GHz; Pol .0°	.100	32.0	3.30	12.41	10.66	10.67	10.22	11.74
Ele 20.0°; R-Zone N	.030	65.0*	-1.00	20.68	18.45	20.96	24.37	22.77
TYPE(R);	.010	88.0	12.00	31.81	27.64	25.41	35.35	30.28
	.003	140.0*	-1.00	48.36	42.23	37.15	62.49	47.07
	.001	180.0*	-1.00	68.08	59.43	42.90	85.06	59.91
Nederhorst HOL	1.000	1.0*	-1.00	.63	.68	.13	.10	.09
(52.2, 5.1) .01km	.300	3.0*	-1.00	1.20	1.37	.47	.39	.35
11.6GHz; Pol .0°	.100	8.0	1.60	2.03	2.20	1.38	1.30	1.18
Ele 27.5°; R-Zone E	.030	17.2	2.60	3.39	3.80	3.04	3.33	3.04
TYPE(B); 36 months	.010	30.0	4.70	5.21	5.70	5.22	6.59	5.95
	.003	47.0	7.50	7.92	8.70	7.75	11.42	10.11
	.001	66.0	9.90	11.15	12.25	10.22	17.32	14.99
Fucino I	1.000	2.4	-1.00	.47	.51	.31	.26	.26
(42.0, 13.6) .68km	.300	5.0	1.20	.89	1.02	.70	.64	.64
11.6GHz; Pol 45.0°	.100	8.5	1.90	1.51	1.63	1.20	1.22	1.22
Ele 31.0°; R-Zone K	.030	15.0	3.00	2.52	2.82	2.11	2.45	2.45
TYPE(B); 60 months	.010	26.0	4.90	3.88	4.22	3.64	4.79	4.74
	.003	46.0	9.00	5.90	6.45	6.33	9.60	9.25
	.001	69.0	12.90	8.30	9.07	9.14	15.75	14.77
Fucino I	1.000	2.4	-1.00	1.09	1.19	.95	.80	.80
(42.0, 13.6) .68km	.300	5.0	2.80	2.10	2.38	1.98	1.81	1.81
17.8GHz; Pol 45.0°	.100	8.5	4.30	3.55	3.82	3.21	3.26	3.26
Ele 31.0°; R-Zone K	.030	15.0	6.80	5.92	6.61	5.28	6.11	6.15
TYPE(B); 60 months	.010	26.0	10.60	9.11	9.91	8.54	11.24	11.26
	.003	46.0	18.80	13.85	15.14	13.93	21.13	20.80
	.001	69.0	26.70	19.49	21.31	19.19	33.09	31.92
Lario I	1.000	3.2	-1.00	1.11	1.21	.47	.38	.37
(46.2, 9.4) .21km	.300	7.0	1.50	2.13	2.42	1.12	.99	.95
11.6GHz; Pol 45.0°	.100	12.5	2.90	3.60	3.88	2.04	2.01	1.94
Ele 32.0°; R-Zone K	.030	27.8	6.50	6.01	6.71	4.71	5.34	5.07
TYPE(B); 60 months	.010	52.0	11.50	9.24	10.05	8.85	11.48	10.57
	.003	84.0	-1.00	14.04	15.35	13.72	20.60	18.37
	.001	117.0	-1.00	19.77	21.61	18.01	30.87	26.80

STATION INFORMATION	TIME %	RAIN RATE	ATTEN (dB)	PREDICTIONS CCIR	FEDI	FRENCH	LIN	SAM
Lario I	1.000	3.2	-1.00	2.41	2.62	1.39	1.14	1.09
(46.2, 9.4) .21km	.300	7.0	3.50	4.61	5.25	3.04	2.71	2.60
17.8GHz; Pol 45.0°	.100	12.5	6.40	7.82	8.41	5.19	5.14	4.96
Ele 32.0°; R-Zone K	.030	27.8	14.00	13.03	14.55	10.97	12.45	11.99
TYPE(B); 60 months	.010	52.0	23.90	20.05	21.81	19.21	24.90	23.48
	.003	84.0	-1.00	30.47	33.31	28.19	42.33	38.91
	.001	117.0	-1.00	42.90	46.88	35.64	61.08	54.92
Spino d'Adda I	1.000	2.0*	-1.00	1.17	1.26	.26	.22	.21
(45.4, 9.5) .08km	.300	5.0	-1.00	2.24	2.53	.73	.66	.64
11.6GHz; Pol 90.0°	.100	9.9	2.60	3.80	4.06	1.50	1.52	1.47
Ele 32.0°; R-Zone K	.030	27.0	6.50	6.33	7.03	4.40	5.14	4.85
TYPE(B); 36 months	.010	55.0	14.00	9.73	10.53	9.11	12.20	11.01
	.003	92.5	22.70	14.79	16.09	14.73	22.93	19.83
	.001	126.0	-1.00	20.82	22.64	18.74	33.38	28.02
Delhi IND	1.000	10.0	1.00	2.26	2.04	1.35	1.05	1.53
(28.4, 77.1) .24km	.300	6.0*	-1.00	4.33	4.10	.67	.56	.81
11.0GHz; Pol .0°	.100	40.0	4.00	7.35	6.57	6.44	5.87	7.96
Ele 45.0°; R-Zone K	.030	23.0*	-1.00	12.25	11.37	2.88	2.95	4.14
TYPE(S); 10 months	.010	100.0	10.00	18.84	17.03	15.95	18.32	23.15
	.003	70.0*	-1.00	28.64	26.02	8.99	11.76	15.31
	.001	140.0	14.00	40.32	36.61	18.88	27.82	34.14
Djahluhur INS	1.000	12.0*	.40	.44	.09	.11	.07	.13
(-6.5, 107.4) .70km	.300	22.9	1.60	.83	.18	.20	.14	.25
4.0GHz; Pol 45.0°	.100	51.0	2.80	1.41	.30	.45	.35	.57
Ele 38.0°; R-Zone P	.030	79.2	3.70	2.36	.51	.65	.56	.90
TYPE(B); 11 months	.010	109.2	4.50	3.63	.77	.82	.80	1.25
	.003	138.5	5.00	5.51	1.17	.94	1.04	1.59
	.001	162.8	5.80	7.76	1.65	1.00	1.24	1.87
Ashizuri J	1.000	7.3	1.90	1.69	1.61	1.14	.96	1.22
(32.8, 132.9) .10km	.300	11.0*	-1.00	3.24	3.23	1.75	1.57	1.99
12.1GHz; Pol 90.0°	.100	31.0	5.00	5.50	5.17	5.53	5.44	6.62
Ele 44.6°; R-Zone M	.030	40.0*	-1.00	9.16	8.95	6.66	7.39	8.87
TYPE(B); 12 months	.010	71.1	10.20	14.10	13.41	11.82	14.75	17.06
	.003	95.0*	-1.00	21.43	20.49	14.66	20.89	23.65
	.001	107.7	13.60	30.17	28.83	15.10	24.29	27.23
Gotenba J	1.000	9.0	8.40	18.65	18.34	26.24	22.17	27.06
(35.1, 138.4) .72km	.300	14.0	15.30	35.75	36.78	34.86	33.91	38.98
35.2GHz; Pol 90.0°	.100	20.0	21.80	60.62	58.93	41.33	47.80	51.23
Ele 15.0°; R-Zone N	.030	65.0*	-1.00	101.04	102.00	104.62	148.57	122.68
TYPE(R); 5 months	.010	95.0*	-1.00	155.45	152.84	124.99	214.04	161.70
	.003	140.0*	-1.00	236.28	233.50	149.05	310.83	214.35
	.001	180.0*	-1.00	332.66	328.60	160.19	395.85	257.43
Hawada J	1.000	5.0*	4.00	5.69	5.56	2.98	2.64	3.20
(34.5, 132.1) .22km	.300	15.0*	7.10	10.90	11.15	8.73	9.91	9.22
11.9GHz; Pol 90.0°	.100	35.0*	10.20	18.48	17.85	18.46	27.46	15.38
Ele 8.4°; R-Zone N	.030	65.0*	-1.00	30.79	30.91	28.99	57.83	23.69
TYPE(R); 12 months	.010	95.0*	-1.00	47.38	46.31	35.70	91.29	31.68
	.003	140.0*	-1.00	72.01	70.75	44.45	145.56	43.46
	.001	180.0*	-1.00	101.38	99.56	49.04	196.95	53.83

STATION INFORMATION	TIME %	RAIN RATE	ATTEN (dB)	PREDICTIONS CCIR	FEDI	FRENCH	LIN	SAM
Izuhara J	1.000	6.2	.70	.95	.91	.86	.71	.89
(34.2, 129.3) .43km	.300	6.0*	-1.00	1.83	1.83	.77	.69	.85
12.1GHz; Pol 90.0°	.100	22.0	2.10	3.10	2.94	3.38	3.28	4.03
Ele 45.2°; R-Zone K	.030	23.0*	-1.00	5.17	5.09	3.19	3.46	4.25
TYPE(B); 12 months	.010	47.3	4.90	7.95	7.62	6.78	8.22	9.88
	.003	70.0*	-1.00	12.09	11.65	9.58	13.17	15.55
	.001	76.3	8.60	17.02	16.39	9.47	14.61	17.17
Kashima J	1.000	5.0	1.00	1.14	1.11	.84	.73	.84
(35.6, 140.7) .04km	.300	6.0*	-1.00	2.18	2.23	.97	.91	1.05
11.7GHz; Pol .0°	.100	16.0	2.00	3.69	3.58	2.89	3.01	3.40
Ele 37.0°; R-Zone K	.030	23.0*	-1.00	6.15	6.19	3.94	4.70	5.16
TYPE(B); 35 months	.010	45.0	6.00	9.47	9.28	7.85	10.67	11.07
	.003	70.0*	-1.00	14.39	14.17	11.65	18.31	18.17
	.001	80.0	10.00	20.26	19.95	12.04	21.56	21.09
Kashima J	1.000	5.0	1.00	.86	.84	.65	.56	.65
(35.6, 140.7) .04km	.300	6.0*	-1.00	1.66	1.68	.76	.70	.82
11.5GHz; Pol .0°	.100	18.0	2.50	2.81	2.68	2.68	2.71	3.12
Ele 47.0°; R-Zone K	.030	23.0*	-1.00	4.68	4.65	3.21	3.66	4.18
TYPE(B); 11 months	.010	42.0*	6.20	7.20	6.96	5.99	7.66	8.57
	.003	70.0*	-1.00	10.94	10.64	9.85	14.33	15.65
	.001	100.0*	-1.00	15.41	14.97	13.54	22.20	23.75
Kashima J	1.000	4.0	2.00	2.07	2.00	1.72	1.49	1.71
(36.0, 140.7) .04km	.300	6.0*	-1.00	3.96	4.01	2.50	2.32	2.66
19.5GHz; Pol 45.0°	.100	15.0	6.00	6.72	6.43	6.20	6.29	7.23
Ele 48.0°; R-Zone K	.030	23.0*	-1.00	11.19	11.12	8.80	10.01	11.49
TYPE(B); 47 months	.010	40.0	16.00	17.22	16.67	14.32	18.28	20.78
	.003	70.0*	-1.00	26.17	25.46	23.14	33.60	37.61
	.001	80.0	31.00	36.85	35.83	23.78	38.86	43.28
Kashima J	1.000	5.0	5.00	5.35	5.19	6.83	5.92	6.79
(36.0, 140.7) .04km	.300	6.0*	-1.00	10.26	10.40	7.63	7.08	8.12
34.5GHz; Pol .0°	.100	18.0	19.50	17.39	16.67	20.43	20.76	23.94
Ele 47.0°; R-Zone K	.030	23.0*	-1.00	28.99	28.85	23.10	26.39	30.44
TYPE(B); 11 months	.010	42.0*	-1.00	44.60	43.23	37.10	47.57	54.57
	.003	70.0*	-1.00	67.79	66.04	53.69	78.44	89.00
	.001	100.0*	-1.00	95.44	92.94	67.59	111.22	124.85
Kesennuma J	1.000	3.6	.80	.77	.80	.60	.54	.57
(38.8, 141.5) .01km	.300	6.0*	-1.00	1.48	1.61	1.02	.99	1.04
12.1GHz; Pol 90.0°	.100	12.9	2.40	2.51	2.58	2.29	2.48	2.58
Ele 34.4°; R-Zone K	.030	23.0*	-1.00	4.18	4.46	3.99	4.97	4.98
TYPE(B); 12 months	.010	33.7	5.90	6.43	6.69	5.51	7.87	7.65
	.003	70.0*	-1.00	9.78	10.22	11.40	18.92	17.15
	.001	71.6	10.60	13.77	14.38	10.25	19.44	17.58
Marugame J	1.000	3.0	2.90	3.30	3.20	2.31	2.11	2.55
(34.3, 133.7) .01km	.300	11.0*	-1.00	6.33	6.42	7.96	10.10	11.05
11.9GHz; Pol 90.0°	.100	15.0	8.70	10.73	10.29	8.28	14.66	11.85
Ele 6.0°; R-Zone M	.030	40.0*	-1.00	17.89	17.82	19.13	47.71	17.81
TYPE(R); 11 months	.010	53.0	-1.00	27.52	26.70	20.31	66.93	21.10
	.003	95.0*	-1.00	41.83	40.78	31.28	135.07	31.87
	.001	120.0*	-1.00	58.90	57.39	33.28	178.90	38.29

STATION INFORMATION	TIME %	RAIN RATE	ATTEN (dB)	CCIR	FEDI	FRENCH	LIN	SAM
				PREDICTIONS				
Marugame J	1.000	3.0	1.70	2.17	2.14	.98	.86	1.04
(34.3, 133.7) .01km	.300	11.0*	-1.00	4.16	4.29	3.98	4.10	4.78
11.9GHz; Pol 90.0°	.100	15.0	5.70	7.05	6.87	4.75	5.95	6.23
Ele 15.0°; R-Zone M	.030	40.0*	-1.00	11.75	11.89	12.33	19.37	14.30
TYPE(R); 11 months	.010	53.0	11.80	18.07	17.82	14.11	27.18	18.19
	.003	95.0*	-1.00	27.47	27.22	23.07	54.86	30.21
	.001	120.0*	-1.00	38.67	38.30	25.54	72.68	37.16
Marugame J	1.000	3.0	1.30	1.17	1.12	.38	.32	.39
(34.3, 133.7) .01km	.300	11.0*	-1.00	2.24	2.25	1.69	1.55	1.87
11.9GHz; Pol 90.0°	.100	15.0	3.00	3.79	3.61	2.24	2.26	2.70
Ele 45.0°; R-Zone M	.030	40.0*	-1.00	6.32	6.25	6.50	7.38	8.45
TYPE(R); 11 months	.010	53.0	5.70	9.73	9.36	8.10	10.37	11.67
	.003	95.0*	-1.00	14.79	14.30	14.34	20.97	22.70
	.001	120.0*	-1.00	20.82	20.13	16.84	27.81	29.57
Matsue J	1.000	4.7	1.30	1.27	1.24	.71	.62	.72
(35.5, 133.0) .02km	.300	6.0*	-1.00	2.44	2.49	.89	.83	.96
12.1GHz; Pol 90.0°	.100	21.8	4.30	4.14	3.98	3.80	3.90	4.41
Ele 42.0°; R-Zone K	.030	23.0*	-1.00	6.90	6.89	3.58	4.16	4.69
TYPE(B); 12 months	.010	54.0	13.30	10.61	10.33	8.82	11.60	12.42
	.003	70.0*	-1.00	16.13	15.78	10.50	15.84	16.64
	.001	87.5	-1.00	22.71	22.21	12.12	20.72	21.38
Minamidaito J	1.000	3.1	1.40	1.67	1.44	.36	.27	.41
(25.8, 131.2) .19km	.300	15.0*	-1.00	3.21	2.89	2.27	1.80	2.72
12.1GHz; Pol 90.0°	.100	22.9	6.00	5.44	4.63	3.47	2.99	4.48
Ele 51.7°; R-Zone N	.030	65.0*	-1.00	9.06	8.01	10.91	10.48	15.16
TYPE(B); 12 months	.010	75.7	16.70	13.94	12.00	11.75	12.59	18.09
	.003	140.0*	-1.00	21.19	18.33	21.77	26.38	36.70
	.001	113.2	20.00	29.84	25.80	15.06	20.43	28.76
Mitaka J	1.000	2.0*	-1.00	1.88	1.83	.64	.55	.64
(35.7, 139.6) .00km	.300	6.0*	-1.00	3.61	3.66	2.04	1.90	2.20
17.0GHz; Pol .0°	.100	12.0*	3.30	6.12	5.87	4.05	4.14	4.78
Ele 45.0°; R-Zone K	.030	23.0*	-1.00	10.19	10.16	7.46	8.60	9.79
TYPE(S);	.010	42.0*	12.80	15.68	15.22	13.03	16.91	18.86
	.003	70.0*	-1.00	23.84	23.25	20.23	30.01	32.67
	.001	100.0*	-1.00	33.56	32.73	26.74	44.79	47.80
Ogasawara J	1.000	3.6	1.00	1.65	1.48	.51	.40	.58
(27.1, 142.2) .05km	.300	11.0*	-1.00	3.16	2.97	1.83	1.52	2.21
12.1GHz; Pol 90.0°	.100	22.6	3.10	5.36	4.76	3.94	3.61	5.02
Ele 42.5°; R-Zone M	.030	40.0*	-1.00	8.94	8.23	6.91	7.17	9.54
TYPE(B); 12 months	.010	67.7	7.90	13.76	12.34	11.51	13.49	17.13
	.003	95.0*	-1.00	20.91	18.85	15.08	20.27	24.92
	.001	118.7	11.00	29.44	26.52	17.41	26.49	31.85
Osaka J	1.000	5.1	1.70	1.38	1.34	.80	.69	.82
(34.7, 135.5) .04km	.300	6.0*	-1.00	2.64	2.68	.90	.83	.99
12.1GHz; Pol 90.0°	.100	26.0	5.60	4.48	4.30	4.76	4.85	5.53
Ele 41.0°; R-Zone K	.030	23.0*	-1.00	7.47	7.44	3.62	4.19	4.81
TYPE(B); 12 months	.010	57.3	15.10	11.49	11.14	9.56	12.54	13.52
	.003	70.0*	-1.00	17.46	17.03	10.59	15.94	16.92
	.001	85.5	-1.00	24.59	23.96	11.88	20.28	21.15

STATION INFORMATION		TIME %	RAIN RATE	ATTEN (dB)	PREDICTIONS CCIR	FEDI	FRENCH	LIN	SAM
Owase	J	1.000	13.3	1.60	1.55	1.49	2.53	2.16	2.58
(34.3, 136.2) .01km		.300	11.0*	-1.00	2.96	3.00	1.87	1.72	2.07
12.1GHz; Pol 90.0°		.100	61.0	11.50	5.02	4.80	13.24	13.46	14.59
Ele 41.5°; R-Zone M		.030	40.0*	-1.00	8.37	8.31	7.02	8.11	9.08
TYPE(B); 12 months		.010	63.0*	20.00	12.88	12.45	10.71	13.99	15.12
		.003	95.0*	-1.00	19.57	19.02	15.28	22.92	23.92
		.001	120.0*	-1.00	27.56	26.77	17.84	30.34	30.99
Sendai	J	1.000	4.0	3.00	1.94	1.98	1.79	1.58	1.70
(38.2, 140.5) .06km		.300	6.0*	-1.00	3.72	3.97	2.59	2.46	2.63
19.5GHz; Pol 45.0°		.100	12.0	6.00	6.31	6.35	5.03	5.22	5.61
Ele 45.0°; R-Zone K		.030	23.0*	-1.00	10.52	11.00	9.06	10.59	11.38
TYPE(B); 11 months		.010	38.0	18.00	16.19	16.48	13.91	18.29	19.49
		.003	70.0*	-1.00	24.60	25.17	23.69	35.56	37.20
		.001	100.0*	-1.00	34.64	35.42	30.97	52.41	54.04
Setagaya	J	1.000	2.0*	-1.00	.95	.92	.24	.21	.24
(35.5, 139.0) .00km		.300	6.0*	-1.00	1.81	1.84	.85	.79	.92
11.8GHz; Pol .0°		.100	12.0*	1.90	3.08	2.95	1.81	1.85	2.14
Ele 45.0°; R-Zone K		.030	23.0*	-1.00	5.13	5.11	3.54	4.08	4.63
TYPE(S);		.010	42.0*	7.30	7.89	7.65	6.56	8.49	9.39
		.003	70.0*	-1.00	11.99	11.69	10.69	15.83	16.97
		.001	100.0*	-1.00	16.89	16.45	14.62	24.45	25.59
Toyokawa	J	1.000	2.0*	1.00	.55	.54	.11	.10	.12
(34.9, 137.4) .01km		.300	6.0*	-1.00	1.06	1.07	.44	.40	.48
9.4GHz; Pol .0°		.100	12.0*	1.80	1.80	1.72	.97	.99	1.16
Ele 45.0°; R-Zone K		.030	23.0*	-1.00	3.00	2.98	1.99	2.28	2.62
TYPE(S); 23 months		.010	42.0*	4.20	4.62	4.46	3.84	4.94	5.49
		.003	70.0*	-1.00	7.02	6.81	6.49	9.54	10.24
		.001	100.0*	-1.00	9.88	9.59	9.09	15.10	15.76
Wakkanai	J	1.000	2.5	1.00	.41	.44	.43	.36	.35
(45.4, 141.7) .06km		.300	6.0*	-1.00	.79	.89	1.11	1.02	.99
12.1GHz; Pol 90.0°		.100	9.9	1.70	1.33	1.43	1.79	1.86	1.80
Ele 29.1°; R-Zone K		.030	23.0*	-1.00	2.22	2.47	4.25	5.10	4.78
TYPE(B); 12 months		.010	20.3	2.90	3.42	3.70	3.17	4.39	4.14
		.003	70.0*	-1.00	5.20	5.65	11.96	19.38	16.56
		.001	52.1	8.00	7.32	7.95	7.29	13.60	11.96
Wakkanai	J	1.000	2.5	1.00	1.40	1.51	1.21	1.01	.98
(45.4, 141.7) .06km		.300	6.0*	-1.00	2.68	3.03	2.89	2.61	2.53
19.5GHz; Pol 45.0°		.100	10.0	2.90	4.54	4.85	4.56	4.54	4.41
Ele 37.0°; R-Zone K		.030	23.0*	-1.00	7.57	8.39	9.91	11.24	11.03
TYPE(B); 12 months		.010	28.4	8.40	11.64	12.57	10.99	14.14	13.85
		.003	70.0*	-1.00	17.70	19.20	25.47	37.74	36.12
		.001	100.0*	14.30	24.91	27.02	33.06	55.63	52.41
Yamagawa	J	1.000	7.0	1.00	1.08	1.01	1.05	.86	1.16
(31.2, 130.6) .08km		.300	11.0*	-1.00	2.07	2.03	1.69	1.48	1.99
12.1GHz; Pol 90.0°		.100	39.0	3.00	3.52	3.25	7.07	6.79	8.65
Ele 47.3°; R-Zone M		.030	40.0*	-1.00	5.86	5.62	6.49	7.00	8.91
TYPE(B); 12 months		.010	50.0	8.00	9.02	8.42	7.56	9.15	11.50
		.003	95.0*	-1.00	13.71	12.87	14.37	19.80	23.88
		.001	120.0*	-1.00	19.30	18.11	16.90	26.22	31.10

STATION INFORMATION		TIME %	RAIN RATE	ATTEN (dB)	CCIR	FEDI	PREDICTIONS FRENCH	LIN	SAM
Yamagawa	J	1.000	7.0	2.00	2.48	2.30	2.95	2.41	3.24
(31.2, 130.6) .08km		.300	11.0*	-1.00	4.76	4.61	4.52	3.94	5.30
19.5GHz; Pol 45.0°		.100	34.0	10.00	8.08	7.38	14.19	13.46	17.97
Ele 53.0°; R-Zone M		.030	40.0*	-1.00	13.46	12.78	15.17	16.06	21.38
TYPE(B); 12 months		.010	50.0	17.00	20.71	19.15	17.34	20.47	27.13
		.003	95.0*	-1.00	31.47	29.26	30.79	41.15	53.51
		.001	120.0*	-1.00	44.31	41.18	35.43	53.06	68.40
Yamaguchi	J	1.000	5.0*	4.60	2.99	2.92	2.80	2.48	3.03
(34.1, 131.3) .12km		.300	10.1	8.50	5.73	5.86	5.16	5.77	7.01
11.9GHz; Pol 90.0°		.100	21.0	12.10	9.71	9.39	9.60	13.92	10.87
Ele 9.2°; R-Zone N		.030	37.0	-1.00	16.18	16.25	14.27	27.52	15.72
TYPE(R); 12 months		.010	57.0	-1.00	24.89	24.35	18.82	46.29	21.36
		.003	140.0*	-1.00	37.83	37.20	43.51	136.47	43.47
		.001	180.0*	-1.00	53.27	52.34	48.14	184.66	53.89
Yokohama	J	1.000	5.0	4.00	2.59	2.49	2.21	1.90	2.23
(35.2, 139.4) .02km		.300	6.0*	-1.00	4.96	5.00	2.52	2.32	2.72
19.5GHz; Pol 45.0°		.100	17.0	8.00	8.41	8.01	7.15	7.20	8.46
Ele 48.0°; R-Zone K		.030	23.0*	-1.00	14.02	13.87	8.84	10.01	11.72
TYPE(B); 23 months		.010	49.0	16.00	21.57	20.78	17.95	22.79	26.23
		.003	70.0*	-1.00	32.78	31.74	23.24	33.59	38.20
		.001	100.0*	-1.00	46.15	44.67	30.43	49.52	55.50
Yokosuka	J	1.000	5.0	3.00	2.99	2.88	2.17	1.85	2.19
(35.1, 139.4) .11km		.300	11.0*	-1.00	5.73	5.78	4.78	4.37	5.17
19.5GHz; Pol 45.0°		.100	16.0	7.00	9.72	9.25	6.57	6.57	7.79
Ele 48.0°; R-Zone M		.030	40.0*	-1.00	16.20	16.01	15.88	17.81	20.86
TYPE(B); 23 months		.010	57.0	27.00	24.93	24.00	20.85	26.18	30.37
		.003	95.0*	-1.00	37.89	36.66	31.97	45.63	51.99
		.001	120.0*	-1.00	53.34	51.59	36.66	58.84	66.37
Yonaguni	J	1.000	5.6	2.70	1.78	1.48	.69	.50	.78
(24.5, 122.4) .20km		.300	15.0*	-1.00	3.42	2.97	2.12	1.63	2.55
12.1GHz; Pol 90.0°		.100	37.8	8.10	5.79	4.76	5.97	4.95	7.76
Ele 57.9°; R-Zone N		.030	65.0*	-1.00	9.66	8.24	10.34	9.51	14.77
TYPE(B); 12 months		.010	82.8	14.30	14.86	12.35	12.48	12.72	19.66
		.003	140.0*	-1.00	22.58	18.86	20.88	23.94	36.45
		.001	117.1	16.70	31.79	26.54	15.11	19.31	29.56
Klang	MLA	1.000	3.0	1.00	4.29	3.55	.39	.28	.45
(3.1, 101.4) .00km		.300	34.0*	-1.00	8.21	7.12	6.93	5.39	8.04
11.8GHz; Pol .0°		.100	63.0	6.00	13.93	11.41	13.40	11.43	16.25
Ele 45.0°; R-Zone P		.030	105.0*	-1.00	23.22	19.75	22.17	21.30	28.96
TYPE(S); 23 months		.010	145.0*	20.00	35.72	29.59	29.22	31.56	41.64
		.003	200.0*	-1.00	54.29	45.20	37.89	46.71	59.71
		.001	250.0*	-1.00	76.43	63.61	44.10	61.30	76.62
Bergen	NOR	1.000	8.0*	1.70	.76	.83	1.90	1.30	1.05
(60.4, 5.3) .00km		.300	13.0*	-1.00	1.45	1.66	3.12	2.36	1.95
11.6GHz; Pol .0°		.100	20.0*	3.40	2.46	2.66	4.66	4.00	3.41
Ele 21.0°; R-Zone J		.030	28.0*	-1.00	4.10	4.60	6.00	6.05	5.21
TYPE(B); 4 months		.010	35.0*	6.40	6.31	6.89	6.79	7.96	6.85
		.003	45.0*	-1.00	9.60	10.53	7.84	10.83	9.30
		.001	55.0*	10.10	13.51	14.82	8.66	13.86	11.82

STATION INFORMATION	TIME %	RAIN RATE	ATTEN (dB)	PREDICTIONS CCIR	FEDI	FRENCH	LIN	SAM
Eik NOR	1.000	3.0*	1.00	.57	.62	.51	.35	.27
(61.3, 5.2) .00km	.300	7.0*	-1.00	1.09	1.25	1.32	.98	.77
11.6GHz; Pol .0°	.100	12.0*	2.00	1.85	2.00	2.28	1.89	1.54
Ele 23.0°; R-Zone G	.030	20.0*	-1.00	3.09	3.47	3.67	3.54	3.03
TYPE(B); 2 months	.010	30.0*	4.20	4.75	5.19	5.24	5.82	5.09
	.003	45.0*	-1.00	7.23	7.93	7.37	9.58	8.45
	.001	65.0*	-1.00	10.17	11.16	10.07	15.04	13.24
Kjeller NOR	1.000	3.0	.80	.87	.95	.55	.38	.31
(60.0, 11.0) .00km	.300	13.0*	-1.00	1.67	1.91	3.02	2.29	1.91
11.6GHz; Pol .0°	.100	15.0	2.10	2.83	3.06	3.18	2.73	2.30
Ele 22.0°; R-Zone J	.030	28.0*	-1.00	4.72	5.30	5.85	5.87	5.09
TYPE(B); 4 months	.010	40.0	6.90	7.26	7.93	7.82	9.09	7.89
	.003	45.0*	-1.00	11.04	12.12	7.68	10.51	9.11
	.001	75.0	12.60	15.54	17.06	12.45	19.67	16.73
Trondheim NOR	1.000	3.0*	.90	.64	.70	.61	.40	.30
(63.6, 10.4) .00km	.300	7.0*	-1.00	1.23	1.40	1.55	1.13	.85
11.6GHz; Pol .0°	.100	12.0*	2.00	2.09	2.24	2.63	2.19	1.69
Ele 18.0°; R-Zone G	.030	20.0*	-1.00	3.48	3.87	4.17	4.09	3.35
TYPE(B); 2 months	.010	30.0*	4.10	5.35	5.80	5.86	6.73	5.64
	.003	45.0*	-1.00	8.13	8.86	8.13	11.07	9.32
	.001	65.0*	-1.00	11.45	12.47	11.00	17.39	14.51
Utibe PNR	1.000	12.0*	1.60	5.73	4.60	3.25	2.31	3.75
(9.1, -79.3) .00km	.300	34.0*	-1.00	10.98	9.22	10.04	7.59	12.16
15.3GHz; Pol .0°	.100	65.0*	10.00	18.62	14.78	19.38	15.90	25.05
Ele 55.0°; R-Zone P	.030	105.0*	-1.00	31.03	25.58	30.09	27.50	42.58
TYPE(R); 9 months	.010	145.0*	-1.00	47.74	38.32	39.08	39.75	60.73
	.003	200.0*	-1.00	72.57	58.55	49.95	57.38	86.38
	.001	250.0*	-1.00	102.17	82.40	57.62	74.04	110.21
Taipei ROC	1.000	15.0	2.20	3.40	3.08	5.66	4.29	5.78
(25.1, 121.6) .00km	.300	15.0*	-1.00	6.51	6.18	4.96	4.29	5.78
11.6GHz; Pol .0°	.100	43.0	8.50	11.04	9.89	15.37	15.64	15.46
Ele 20.0°; R-Zone N	.030	65.0*	-1.00	18.40	17.12	21.00	25.96	22.77
TYPE(R);	.010	80.0	-1.00	28.30	25.66	22.64	33.50	27.68
	.003	140.0*	-1.00	43.02	39.20	37.21	66.56	47.07
	.001	180.0*	-1.00	60.57	55.16	42.96	90.61	59.91
Stockholm S	1.000	1.0*	-1.00	.41	.45	.14	.10	.08
(59.3, 18.1) .06km	.300	3.0*	-1.00	.79	.90	.49	.37	.30
11.6GHz; Pol .0°	.100	5.0	.70	1.34	1.45	.81	.70	.57
Ele 22.4°; R-Zone E	.030	10.1	1.80	2.23	2.51	1.65	1.65	1.35
TYPE(B); 12 months	.010	22.0	3.90	3.43	3.76	3.71	4.29	3.72
	.003	35.5	6.60	5.21	5.74	5.68	7.71	6.75
	.001	46.0	9.30	7.34	8.08	6.77	10.60	9.26
Stockholm S	1.000	1.0*	-1.00	.62	.68	.27	.18	.15
(59.3, 18.1) .06km	.300	3.0*	-1.00	1.19	1.37	.86	.65	.53
14.5GHz; Pol 45.0°	.100	5.0	1.20	2.02	2.19	1.37	1.18	.96
Ele 22.4°; R-Zone E	.030	10.1	2.50	3.37	3.79	2.65	2.64	2.16
TYPE(B); 12 months	.010	22.0	5.00	5.18	5.67	5.60	6.48	5.66
	.003	35.5	8.70	7.88	8.67	8.28	11.24	9.96
	.001	46.0	11.40	11.09	12.20	9.67	15.14	13.43

STATION INFORMATION		TIME %	RAIN RATE	ATTEN (dB)	PREDICTIONS CCIR	FEDI	FRENCH	LIN	SAM
Singapore	SNG	1.000	3.5	1.20	3.64	3.05	.48	.35	.56
(1.3, 103.9)	.00km	.300	34.0*	-1.00	6.98	6.11	7.18	5.64	8.16
11.6GHz; Pol	.0°	.100	57.0	3.90	11.83	9.79	12.26	10.61	14.61
Ele 41.0°; R-Zone P		.030	105.0*	-1.00	19.72	16.95	22.86	22.43	28.89
TYPE(R);		.010	124.0	12.00	30.34	25.39	24.79	27.50	34.75
		.003	200.0*	-1.00	46.12	38.79	38.80	49.38	58.99
		.001	250.0*	-1.00	64.93	54.59	45.01	64.91	75.45
Austin	USA	1.000	4.0*	-1.00	.91	.84	.46	.37	.52
(30.4, -97.7)	.24km	.300	5.0	1.30	1.75	1.69	.57	.49	.68
11.7GHz; Pol 45.0°		.100	10.0	2.20	2.97	2.70	1.22	1.13	1.59
Ele 50.0°; R-Zone M		.030	28.0	5.20	4.96	4.68	3.83	3.98	5.44
TYPE(B); 12 months		.010	47.0	8.70	7.62	7.01	6.45	7.47	10.02
		.003	67.0	17.50	11.59	10.71	8.77	11.50	15.17
		.001	93.0	-1.00	16.32	15.07	11.67	17.14	22.22
Austin	USA	1.000	4.0*	-1.00	1.41	1.30	.46	.37	.52
(30.4, -97.7)	.24km	.300	5.0	1.00	2.70	2.60	.57	.49	.68
11.7GHz; Pol 45.0°		.100	10.0	2.70	4.58	4.16	1.22	1.13	1.59
Ele 50.0°; R-Zone M		.030	36.0	9.50	7.63	7.20	5.20	5.40	7.32
TYPE(B); 12 months		.010	67.0	20.50	11.74	10.79	9.93	11.50	15.17
		.003	97.0	-1.00	17.84	16.49	13.77	18.05	23.33
		.001	120.0	-1.00	25.12	23.21	15.92	23.38	29.85
Austin	USA	1.000	4.0*	-1.00	1.08	1.00	.46	.37	.52
(30.4, -97.7)	.24km	.300	5.0	1.20	2.08	2.00	.57	.49	.68
11.7GHz; Pol 45.0°		.100	16.0	2.90	3.52	3.20	2.16	2.01	2.79
Ele 50.0°; R-Zone M		.030	35.0	7.00	5.87	5.54	5.03	5.22	7.08
TYPE(B); 12 months		.010	54.0	11.40	9.03	8.30	7.64	8.84	11.79
		.003	85.0	16.50	13.72	12.68	11.72	15.37	20.01
		.001	116.0	19.10	19.32	17.85	15.27	22.44	28.70
Austin	USA	1.000	8.0	.60	1.36	1.25	1.48	1.19	1.66
(30.4, -97.7)	.24km	.300	11.0*	1.50	2.61	2.50	2.02	1.72	2.41
13.6GHz; Pol 90.0°		.100	15.0	3.80	4.42	4.01	2.67	2.47	3.45
Ele 52.0°; R-Zone M		.030	40.0*	10.00	7.37	6.93	7.52	7.76	10.66
TYPE(R); 26 months		.010	54.0	-1.00	11.34	10.39	9.59	11.01	14.98
		.003	95.0*	-1.00	17.23	15.87	16.40	21.29	28.34
		.001	92.0	-1.00	24.26	22.33	14.12	20.50	27.34
Austin	USA	1.000	9.0	1.00	2.56	2.35	3.48	2.79	3.90
(30.4, -97.7)	.24km	.300	10.0	2.60	4.91	4.71	3.67	3.13	4.37
19.0GHz; Pol 90.0°		.100	18.0	6.80	8.32	7.54	6.39	5.92	8.29
Ele 52.0°; R-Zone M		.030	35.0	16.60	13.87	13.05	11.82	12.20	16.96
TYPE(B); 22 months		.010	57.0	23.90	21.33	19.55	18.04	20.72	28.50
		.003	78.0	30.00	32.43	29.87	22.46	29.14	39.70
		.001	95.0	-1.00	45.65	42.03	24.87	36.11	48.85
Austin	USA	1.000	9.0	1.80	4.80	4.40	7.44	5.96	8.34
(30.4, -97.7)	.24km	.300	10.0	5.80	9.20	8.83	7.78	6.63	9.28
28.6GHz; Pol 90.0°		.100	18.0	15.50	15.61	14.14	13.02	12.05	16.95
Ele 52.0°; R-Zone M		.030	35.0	33.40	26.01	24.47	22.96	23.68	33.19
TYPE(R); 22 months		.010	57.0	-1.00	40.02	36.67	33.85	38.87	54.04
		.003	78.0	-1.00	60.82	56.02	41.19	53.45	73.77
		.001	95.0	-1.00	85.63	78.84	44.98	65.31	89.64

STATION INFORMATION	TIME %	RAIN RATE	ATTEN (dB)	PREDICTIONS CCIR	FEDI	FRENCH	LIN	SAM
Blacksburg USA	1.000	1.0	1.10	1.23	1.25	.11	.09	.10
(37.2, -80.5) .64km	.300	4.0	3.00	2.37	2.50	.54	.49	.56
11.7GHz; Pol 45.0°	.100	10.0	4.00	4.01	4.01	1.48	1.51	1.70
Ele 33.0°; R-Zone K	.030	37.0	8.00	6.69	6.94	6.39	7.43	7.86
TYPE(B); 11 months	.010	54.0	13.00	10.29	10.40	8.92	11.77	12.08
	.003	86.0	19.00	15.64	15.89	13.66	20.73	20.41
	.001	106.0	24.00	22.02	22.36	15.52	26.75	25.79
Blacksburg USA	1.000	.1	2.00	.65	.66	.01	.01	.01
(37.2, -80.5) .64km	.300	6.0*	-1.00	1.25	1.32	.88	.81	.91
11.7GHz; Pol 45.0°	.100	7.0	3.70	2.12	2.12	.96	.98	1.10
Ele 33.0°; R-Zone K	.030	23.0*	-1.00	3.54	3.67	3.58	4.16	4.54
TYPE(B); 12 months	.010	32.0	6.00	5.44	5.50	4.72	6.22	6.65
	.003	78.0	11.00	8.27	8.40	12.13	18.41	18.30
	.001	99.0	13.00	11.64	11.83	14.28	24.61	23.90
Blacksburg USA	1.000	1.1	.70	1.15	1.16	.12	.10	.12
(37.2, -80.5) .64km	.300	5.0	2.70	2.21	2.34	.70	.65	.73
11.7GHz; Pol 45.0°	.100	12.0	3.70	3.74	3.74	1.85	1.89	2.11
Ele 33.0°; R-Zone K	.030	27.0	6.30	6.24	6.48	4.35	5.06	5.47
TYPE(B); 31 months	.010	51.0	10.30	9.60	9.70	8.32	10.98	11.33
	.003	87.0	16.00	14.59	14.82	13.86	21.03	20.68
	.001	125.0	23.10	20.54	20.86	18.97	32.69	30.99
Blacksburg USA	1.000	2.0*	-1.00	1.60	1.60	.67	.57	.64
(37.2, -80.5) .64km	.300	6.0*	-1.00	3.06	3.20	2.09	1.89	2.13
19.0GHz; Pol 52.5°	.100	9.0	5.00	5.19	5.13	3.00	2.95	3.32
Ele 46.0°; R-Zone K	.030	19.0	11.00	8.65	8.87	6.10	6.66	7.66
TYPE(B); 11 months	.010	38.0	14.00	13.31	13.30	11.70	14.19	16.46
	.003	61.0	23.00	20.24	20.31	17.39	23.78	27.53
	.001	104.0	26.00	28.49	28.58	27.85	42.56	48.85
Blacksburg USA	1.000	2.0*	-1.00	1.59	1.59	.68	.58	.65
(37.2, -80.5) .64km	.300	5.0	5.00	3.05	3.19	1.74	1.58	1.78
19.0GHz; Pol 37.2°	.100	8.0	8.00	5.17	5.11	2.69	2.64	2.97
Ele 46.0°; R-Zone K	.030	18.0	12.00	8.62	8.84	5.89	6.42	7.37
TYPE(B); 11 months	.010	37.0	16.00	13.27	13.25	11.66	14.14	16.39
	.003	61.0	26.00	20.17	20.24	17.88	24.45	28.29
	.001	100.0*	-1.00	28.39	28.49	27.50	42.01	48.22
Blacksburg USA	1.000	1.0	2.00	1.85	1.85	.32	.27	.31
(37.2, -80.5) .64km	.300	4.0	3.40	3.55	3.71	1.37	1.24	1.39
19.0GHz; Pol 52.5°	.100	8.0	5.10	6.02	5.95	2.68	2.63	2.97
Ele 45.0°; R-Zone K	.030	21.0	10.00	10.03	10.29	6.90	7.55	8.68
TYPE(B); 32 months	.010	43.0	16.90	15.42	15.42	13.55	16.51	19.06
	.003	74.0	23.80	23.44	23.56	21.70	29.85	34.25
	.001	104.0	-1.00	33.01	33.16	28.12	43.27	49.27
Blacksburg USA	1.000	1.0	3.10	1.90	1.90	.32	.28	.31
(37.2, -80.5) .64km	.300	4.0	5.00	3.65	3.81	1.39	1.26	1.42
19.0GHz; Pol 37.2°	.100	8.0	6.00	6.18	6.11	2.73	2.69	3.03
Ele 45.0°; R-Zone K	.030	21.0	11.00	10.30	10.58	7.07	7.74	8.89
TYPE(B); 32 months	.010	43.0	19.00	15.85	15.85	13.92	16.96	19.58
	.003	74.0	26.00	24.09	24.21	22.35	30.75	35.25
	.001	104.0	30.00	33.92	34.07	29.01	44.64	50.78

STATION INFORMATION	TIME %	RAIN RATE	ATTEN (dB)	PREDICTIONS CCIR	FEDI	FRENCH	LIN	SAM
Blacksburg USA	1.000	1.0	5.50	4.04	4.04	.80	.68	.77
(37.2, -80.5) .64km	.300	4.0	8.30	7.75	8.10	3.10	2.81	3.16
28.6GHz; Pol 52.5°	.100	8.0	12.10	13.13	12.98	5.78	5.69	6.40
Ele 45.0°; R-Zone K	.030	24.0	19.70	21.89	22.47	15.91	17.42	20.17
TYPE(B); 40 months	.010	49.0	27.70	33.68	33.67	29.58	36.04	42.01
	.003	70.0*	-1.00	51.19	51.44	37.68	51.83	60.30
	.001	100.0*	-1.00	72.07	72.39	48.45	74.54	86.29
Blacksburg USA	1.000	2.0*	-1.00	1.45	1.46	.69	.61	.68
(37.2, -80.5) .64km	.300	6.0*	4.00	2.78	2.92	2.19	2.32	2.61
11.6GHz; Pol 45.0°	.100	12.0*	6.00	4.71	4.68	4.10	5.41	5.68
Ele 10.7°; R-Zone K	.030	17.0	10.00	7.85	8.10	4.90	8.27	7.57
TYPE(B); 12 months	.010	35.0	16.00	12.08	12.14	9.51	19.97	13.66
	.003	60.0	20.00	18.36	18.54	14.69	38.55	21.37
	.001	100.0	22.00	25.85	26.10	22.70	71.90	33.08
Blacksburg USA	1.000	2.0*	-1.00	1.97	1.98	.69	.61	.68
(37.2, -80.5) .64km	.300	6.0*	4.00	3.78	3.97	2.19	2.32	2.61
11.6GHz; Pol 45.0°	.100	10.0	6.00	6.40	6.36	3.28	4.33	4.87
Ele 10.7°; R-Zone K	.030	25.0	11.00	10.67	11.01	7.84	13.24	10.37
TYPE(B); 12 months	.010	45.0	16.00	16.41	16.50	12.92	27.13	16.81
	.003	80.0	20.00	24.95	25.20	20.86	54.76	27.29
	.001	100.0	24.00	35.13	35.46	22.70	71.90	33.08
Blacksburg USA	1.000	2.0*	-1.00	2.52	2.53	.69	.61	.68
(37.2, -80.5) .64km	.300	6.0*	-1.00	4.82	5.07	2.19	2.32	2.61
11.6GHz; Pol 45.0°	.100	12.0*	7.00	8.18	8.12	4.10	5.41	5.68
Ele 10.7°; R-Zone K	.030	25.0	13.00	13.63	14.06	7.84	13.24	10.37
TYPE(B); 12 months	.010	55.0	19.00	20.97	21.07	16.51	34.66	19.87
	.003	80.0	22.00	31.87	32.19	20.86	54.76	27.29
	.001	95.0	24.00	44.87	45.30	21.33	67.54	31.64
Blacksburg USA	1.000	2.0*	-1.00	2.02	2.03	.69	.61	.68
(37.2, -80.5) .64km	.300	3.0	3.80	3.88	4.08	.94	1.00	1.12
11.6GHz; Pol 45.0°	.100	8.0	6.60	6.58	6.53	2.50	3.30	3.71
Ele 10.7°; R-Zone K	.030	21.0	12.00	10.96	11.31	6.34	10.70	9.00
TYPE(B); 36 months	.010	46.0	16.90	16.86	16.94	13.27	27.87	17.12
	.003	77.0	21.30	25.63	25.88	19.91	52.26	26.41
	.001	102.0	23.20	36.08	36.43	23.26	73.66	33.65
Clarksburg USA	1.000	2.0	1.10	5.85	6.15	1.56	1.40	1.46
(39.2, -77.3) .18km	.300	6.0	4.50	11.22	12.33	4.67	4.73	4.93
19.0GHz; Pol .0°	.100	12.5	10.00	19.02	19.76	9.06	10.66	10.80
Ele 21.0°; R-Zone K	.030	31.0	19.00	31.70	34.20	20.63	29.12	25.63
TYPE(B); 12 months	.010	67.0	25.00	48.77	51.25	40.85	68.35	52.28
	.003	70.0*	-1.00	74.12	78.29	35.76	71.75	54.42
	.001	100.0*	-1.00	104.36	110.18	45.29	106.48	75.38
Clarksburg USA	1.000	2.8	-1.00	2.38	2.48	1.15	1.02	1.07
(39.2, -77.3) .18km	.300	6.0	2.50	4.55	4.98	2.45	2.33	2.43
19.0GHz; Pol 90.0°	.100	11.0	6.00	7.72	7.98	4.29	4.50	4.70
Ele 41.0°; R-Zone K	.030	25.0	14.00	12.87	13.81	9.24	10.95	11.40
TYPE(B); 12 months	.010	50.0	25.00	19.80	20.70	17.36	23.21	23.71
	.003	70.0*	-1.00	30.10	31.62	21.84	33.43	33.69
	.001	100.0*	-1.00	42.38	44.50	28.44	49.20	48.73

STATION INFORMATION	TIME %	RAIN RATE	ATTEN (dB)	CCIR	FEDI	PREDICTIONS FRENCH	LIN	SAM
Clarksburg USA	1.000	2.8	.80	2.68	2.80	1.23	1.09	1.14
(39.2, -77.3) .18km	.300	6.0	3.20	5.14	5.62	2.65	2.53	2.64
19.0GHz; Pol .0°	.100	11.0	7.40	8.71	9.00	4.71	4.94	5.15
Ele 41.0°; R-Zone K	.030	25.0	17.00	14.52	15.59	10.29	12.20	12.67
TYPE(B); 12 months	.010	50.0	27.00	22.34	23.35	19.59	26.19	26.67
	.003	70.0*	-1.00	33.96	35.68	24.80	37.95	38.10
	.001	100.0*	-1.00	47.82	50.21	32.50	56.23	55.43
Clarksburg USA	1.000	2.2	.80	3.32	3.46	.85	.75	.78
(39.2, -77.3) .18km	.300	6.5	5.00	6.37	6.95	2.56	2.43	2.54
19.0GHz; Pol 90.0°	.100	17.0	9.80	10.79	11.13	6.63	6.90	7.25
Ele 43.5°; R-Zone K	.030	40.0	16.00	17.99	19.26	14.89	17.45	18.20
TYPE(B); 24 months	.010	70.0	24.00	27.68	28.86	24.31	32.02	32.90
	.003	70.0*	-1.00	42.07	44.09	21.31	32.02	32.90
	.001	100.0*	-1.00	59.23	62.04	27.83	47.14	47.78
Clarksburg USA	1.000	2.0	3.00	8.98	9.43	3.37	3.03	3.16
(39.2, -77.3) .18km	.300	6.0	7.90	17.20	18.92	9.06	9.17	9.57
28.6GHz; Pol 90.0°	.100	12.5	15.60	29.17	30.31	16.36	19.25	19.59
Ele 21.0°; R-Zone K	.030	30.0	27.00	48.62	52.46	32.99	46.58	42.22
TYPE(B); 12 months	.010	67.0	-1.00	74.79	78.60	62.66	104.83	83.53
	.003	70.0*	-1.00	113.69	120.08	54.61	109.57	86.65
	.001	100.0*	-1.00	160.06	168.99	66.81	157.06	116.74
Clarksburg USA	1.000	2.8	1.80	4.50	4.71	2.67	2.37	2.47
(39.2, -77.3) .18km	.300	6.0	6.00	8.63	9.44	5.38	5.13	5.35
28.6GHz; Pol 90.0°	.100	11.0	13.40	14.64	15.13	9.04	9.49	9.91
Ele 41.0°; R-Zone K	.030	25.0	24.50	24.40	26.18	18.39	21.80	22.83
TYPE(B); 12 months	.010	50.0	-1.00	37.53	39.23	32.91	44.00	45.50
	.003	70.0*	-1.00	57.05	59.93	40.43	61.88	63.29
	.001	100.0*	-1.00	80.32	84.34	51.33	88.82	89.56
Clarksburg USA	1.000	2.0	4.20	6.15	6.41	1.82	1.61	1.68
(39.2, -77.3) .18km	.300	6.5	10.20	11.78	12.85	5.60	5.32	5.55
28.6GHz; Pol 90.0°	.100	17.0	17.30	19.97	20.59	13.55	14.11	14.87
Ele 43.5°; R-Zone K	.030	40.0	27.00	33.29	35.64	28.66	33.60	35.37
TYPE(B); 24 months	.010	70.0	-1.00	51.21	53.40	44.98	59.25	61.72
	.003	70.0*	-1.00	77.84	81.58	39.43	59.25	61.72
	.001	100.0*	-1.00	109.59	114.81	50.21	85.07	87.66
Clarksburg USA	1.000	2.0	.50	2.45	2.58	.43	.39	.40
(39.2, -77.3) .18km	.300	6.0	1.50	4.70	5.17	1.47	1.48	1.55
11.6GHz; Pol .0°	.100	12.5	3.00	7.97	8.28	3.10	3.65	3.68
Ele 21.0°; R-Zone K	.030	30.0	5.10	13.29	14.34	7.57	10.69	9.19
TYPE(R); 12 months	.010	67.0	6.80	20.44	21.49	17.13	28.65	20.86
	.003	70.0*	-1.00	31.07	32.82	15.07	30.24	21.81
	.001	100.0*	-1.00	43.75	46.19	19.92	46.84	31.27
Clarksburg USA	1.000	2.8	.30	1.09	1.14	.35	.31	.33
(39.2, -77.3) .18km	.300	6.0	1.00	2.09	2.29	.83	.79	.83
11.6GHz; Pol .0°	.100	11.0	2.30	3.54	3.66	1.59	1.67	1.74
Ele 41.0°; R-Zone K	.030	25.0	4.10	5.91	6.34	3.85	4.56	4.68
TYPE(R); 12 months	.010	50.0	8.50	9.09	9.50	7.97	10.65	10.62
	.003	70.0*	-1.00	13.82	14.51	10.51	16.09	15.74
	.001	100.0*	-1.00	19.45	20.42	14.39	24.90	23.80

STATION INFORMATION	TIME %	RAIN RATE	ATTEN (dB)	PREDICTIONS				
				CCIR	FEDI	FRENCH	LIN	SAM
Clarksburg USA	1.000	2.0*	-1.00	1.91	1.99	.23	.20	.21
(39.2, -77.3) .18km	.300	6.0	2.40	3.66	4.00	.82	.78	.81
11.6GHz; Pol .0°	.100	16.0	3.80	6.20	6.40	2.47	2.58	2.69
Ele 42.0°; R-Zone K	.030	39.0	6.30	10.34	11.09	6.52	7.69	7.81
TYPE(R); 12 months	.010	80.0	10.20	15.91	16.61	13.96	18.55	18.17
	.003	70.0*	-1.00	24.18	25.38	10.37	15.75	15.54
	.001	100.0*	-1.00	34.04	35.71	14.21	24.38	23.55
Clarksburg USA	1.000	2.5	.20	1.56	1.62	.29	.26	.27
(39.2, -77.3) .18km	.300	6.0	1.00	2.98	3.26	.79	.75	.79
11.6GHz; Pol .0°	.100	16.0	2.50	5.06	5.22	2.41	2.51	2.62
Ele 43.5°; R-Zone K	.030	42.0	6.00	8.43	9.03	6.97	8.17	8.35
TYPE(R); 12 months	.010	69.0	8.90	12.97	13.53	11.39	15.01	15.01
	.003	70.0*	-1.00	19.72	20.66	10.17	15.28	15.27
	.001	100.0*	-1.00	27.76	29.08	13.95	23.64	23.19
Clarksburg USA	1.000	2.0	1.00	4.82	5.07	1.42	1.28	1.33
(39.2, -77.3) .18km	.300	6.0	3.80	9.25	10.17	4.12	4.18	4.35
19.0GHz; Pol 90.0°	.100	12.5	8.60	15.68	16.29	7.83	9.21	9.35
Ele 21.0°; R-Zone K	.030	30.0	16.00	26.13	28.20	16.78	23.69	21.11
TYPE(B); 12 months	.010	67.0	22.20	40.20	42.25	33.68	56.35	43.61
	.003	70.0*	-1.00	61.11	64.54	29.44	59.07	45.35
	.001	100.0*	-1.00	86.03	90.83	36.92	86.78	62.31
Etam USA	1.000	2.0*	1.40	1.41	1.49	.45	.40	.42
(39.3, -79.7) .56km	.300	6.0*	2.80	2.71	2.99	1.53	1.54	1.61
11.6GHz; Pol .0°	.100	12.0*	5.80	4.59	4.79	3.07	3.61	3.66
Ele 18.0°; R-Zone K	.030	23.0*	11.50	7.65	8.29	5.66	8.01	7.22
TYPE(R); 12 months	.010	42.0*	-1.00	11.77	12.42	9.96	16.78	13.34
	.003	70.0*	-1.00	17.89	18.98	15.48	31.41	22.27
	.001	100.0*	-1.00	25.18	26.71	20.41	48.66	31.78
Grant Park USA	1.000	2.0*	-1.00	2.88	3.07	1.44	1.28	1.29
(41.1, -87.4) .10km	.300	6.0*	-1.00	5.52	6.16	4.16	4.19	4.23
19.0GHz; Pol 90.0°	.100	12.0*	9.50	9.36	9.87	7.56	8.85	8.74
Ele 21.0°; R-Zone K	.030	23.0*	-1.00	15.59	17.09	12.68	17.86	16.18
TYPE(B); 12 months	.010	42.0*	-1.00	23.99	25.60	20.47	34.19	28.18
	.003	70.0*	-1.00	36.47	39.11	29.59	59.32	44.75
	.001	100.0*	-1.00	51.34	55.04	37.08	87.14	61.62
Grant Park USA	1.000	2.0*	-1.00	1.92	2.04	.80	.70	.71
(41.1, -87.4) .10km	.300	6.0*	-1.00	3.68	4.09	2.44	2.31	2.33
19.0GHz; Pol 90.0°	.100	12.0*	9.00	6.24	6.56	4.70	4.89	4.95
Ele 41.8°; R-Zone K	.030	23.0*	-1.00	10.39	11.35	8.42	9.90	10.05
TYPE(B); 12 months	.010	42.0*	-1.00	15.99	17.01	14.34	19.02	19.14
	.003	70.0*	-1.00	24.30	25.98	21.80	33.09	32.79
	.001	100.0*	-1.00	34.22	36.56	28.39	48.71	47.58
Grant Park USA	1.000	2.0*	-1.00	4.71	5.04	2.69	2.39	2.41
(41.1, -87.4) .10km	.300	6.0*	-1.00	9.02	10.11	7.40	7.25	7.30
28.6GHz; Pol 90.0°	.100	12.0*	17.00	15.30	16.19	13.14	14.60	14.60
Ele 27.3°; R-Zone K	.030	23.0*	-1.00	25.51	28.02	21.66	28.17	27.09
TYPE(B); 12 months	.010	42.0*	-1.00	39.24	41.99	34.28	51.77	47.36
	.003	70.0*	-1.00	59.64	64.15	48.79	86.76	75.39
	.001	100.0*	-1.00	83.97	90.28	60.54	124.41	103.89

STATION INFORMATION	TIME %	RAIN RATE	ATTEN (dB)	CCIR	FEDI	PREDICTIONS FRENCH	LIN	SAM
Grant Park USA	1.000	2.0*	-1.00	3.68	3.92	1.89	1.67	1.68
(41.1, -87.4) .10km	.300	6.0*	-1.00	7.06	7.85	5.36	5.08	5.12
28.6GHz; Pol 90.0°	.100	12.0*	20.00	11.96	12.58	9.84	10.25	10.38
Ele 41.8°; R-Zone K	.030	23.0*	-1.00	19.94	21.77	16.85	19.82	20.23
TYPE(B); 12 months	.010	42.0*	-1.00	30.68	32.63	27.51	36.50	37.09
	.003	70.0*	-1.00	46.63	49.84	40.35	61.25	61.56
	.001	100.0*	-1.00	65.65	70.15	51.25	87.92	87.36
Greenbelt USA	1.000	3.0	.30	1.75	1.82	.51	.45	.48
(38.5, -77.0) .20km	.300	8.0	1.00	3.36	3.66	1.53	1.49	1.59
11.7GHz; Pol 45.0°	.100	19.0	1.80	5.70	5.86	3.89	4.27	4.31
Ele 29.0°; R-Zone K	.030	35.0	4.60	9.50	10.14	7.04	8.98	8.48
TYPE(B); 12 months	.010	63.0	8.90	14.62	15.19	12.47	18.36	16.09
	.003	94.0	17.00	22.22	23.20	17.34	29.89	24.77
	.001	133.0	-1.00	31.29	32.66	22.98	45.60	35.93
Greenbelt USA	1.000	3.0	.50	1.65	1.72	.51	.45	.48
(38.5, -77.0) .20km	.300	7.0	1.20	3.17	3.44	1.30	1.27	1.35
11.7GHz; Pol 45.0°	.100	14.0	2.20	5.37	5.52	2.68	2.94	3.05
Ele 29.0°; R-Zone K	.030	30.0	5.10	8.95	9.55	5.84	7.44	7.15
TYPE(B); 12 months	.010	60.0	12.10	13.78	14.31	11.75	17.30	15.26
	.003	96.0	20.30	20.94	21.87	17.79	30.66	25.34
	.001	130.0	26.30	29.48	30.77	22.35	44.35	35.06
Greenbelt USA	1.000	3.0	.60	1.32	1.38	.51	.45	.48
(38.5, -77.0) .20km	.300	7.0	1.10	2.54	2.76	1.30	1.27	1.35
11.7GHz; Pol 45.0°	.100	14.0	1.70	4.30	4.42	2.68	2.94	3.05
Ele 29.0°; R-Zone K	.030	30.0	5.90	7.17	7.65	5.84	7.44	7.15
TYPE(B); 12 months	.010	50.0	14.00	11.03	11.46	9.41	13.86	12.52
	.003	90.0	26.00	16.77	17.51	16.44	28.35	23.64
	.001	120.0	29.40	23.61	24.65	20.28	40.24	32.19
Greenbelt USA	1.000	4.0	.50	1.65	1.72	.72	.64	.68
(38.5, -77.0) .20km	.300	7.0	1.10	3.17	3.44	1.30	1.27	1.35
11.7GHz; Pol 45.0°	.100	15.0	1.80	5.37	5.52	2.92	3.20	3.30
Ele 29.0°; R-Zone K	.030	32.0	5.00	8.95	9.55	6.31	8.05	7.68
TYPE(B); 36 months	.010	60.0	11.90	13.78	14.31	11.75	17.30	15.26
	.003	94.0	21.00	20.94	21.87	17.34	29.89	24.77
	.001	124.0	27.80	29.48	30.77	21.10	41.87	33.34
Holmdel USA	1.000	2.0*	.60	1.11	1.18	.34	.30	.30
(40.4, -74.1) .11km	.300	6.0*	1.80	2.13	2.38	1.16	1.15	1.16
11.7GHz; Pol 45.0°	.100	12.0*	3.40	3.60	3.81	2.37	2.66	2.66
Ele 27.0°; R-Zone K	.030	23.0*	8.40	6.01	6.59	4.47	5.88	5.50
TYPE(B); 12 months	.010	42.0*	-1.00	9.24	9.87	8.00	12.24	10.61
	.003	70.0*	-1.00	14.05	15.08	12.64	22.80	18.39
	.001	100.0*	-1.00	19.78	21.22	16.88	35.21	26.89
Holmdel USA	1.000	2.0*	.60	1.11	1.18	.34	.30	.30
(40.4, -74.1) .11km	.300	6.0*	1.80	2.13	2.38	1.16	1.15	1.16
11.7GHz; Pol 45.0°	.100	12.0*	3.00	3.60	3.81	2.37	2.66	2.66
Ele 27.0°; R-Zone K	.030	23.0*	7.30	6.01	6.59	4.47	5.88	5.50
TYPE(B); 12 months	.010	42.0*	13.50	9.24	9.87	8.00	12.24	10.61
	.003	70.0*	23.70	14.05	15.08	12.64	22.80	18.39
	.001	100.0*	-1.00	19.78	21.22	16.88	35.21	26.89

STATION INFORMATION	TIME %	RAIN RATE	ATTEN (dB)	CCIR	FEDI	PREDICTIONS FRENCH	LIN	SAM
Holmdel USA	1.000	2.0*	.60	1.11	1.18	.34	.30	.30
(40.4, -74.1) .11km	.300	6.0*	1.50	2.13	2.38	1.16	1.15	1.16
11.7GHz; Pol 45.0°	.100	12.0*	2.40	3.60	3.81	2.37	2.66	2.66
Ele 27.0°; R-Zone K	.030	23.0*	4.80	6.01	6.59	4.47	5.88	5.50
TYPE(B); 12 months	.010	42.0*	9.50	9.24	9.87	8.00	12.24	10.61
	.003	70.0*	19.50	14.05	15.08	12.64	22.80	18.39
	.001	100.0*	30.00	19.78	21.22	16.88	35.21	26.89
Holmdel USA	1.000	2.0*	2.50	3.13	3.33	1.62	1.46	1.48
(40.4, -74.1) .11km	.300	6.0*	5.50	6.01	6.68	4.62	4.77	4.84
19.0GHz; Pol 90.0°	.100	12.0*	12.00	10.19	10.70	8.27	10.08	9.94
Ele 18.5°; R-Zone K	.030	23.0*	25.00	16.98	18.52	13.69	20.32	17.92
TYPE(B); 24 months	.010	42.0*	40.00	26.12	27.75	21.85	38.90	30.48
	.003	70.0*	-1.00	39.71	42.39	31.28	67.47	47.51
	.001	100.0*	-1.00	55.90	59.65	38.91	99.10	64.63
Holmdel USA	1.000	2.0*	2.00	2.06	2.19	.85	.76	.77
(40.4, -74.1) .11km	.300	6.0*	3.80	3.94	4.39	2.61	2.51	2.55
19.0GHz; Pol 69.0°	.100	12.0*	6.50	6.68	7.03	5.02	5.33	5.41
Ele 38.6°; R-Zone K	.030	23.0*	13.50	11.14	12.17	8.94	10.80	10.87
TYPE(B); 12 months	.010	42.0*	22.00	17.14	18.23	15.18	20.76	20.51
	.003	70.0*	44.00	26.05	27.85	22.98	36.15	34.87
	.001	100.0*	-1.00	36.67	39.20	29.83	53.24	50.31
Holmdel USA	1.000	2.0*	2.00	2.26	2.40	.90	.80	.81
(40.4, -74.1) .11km	.300	6.0*	4.00	4.33	4.82	2.79	2.68	2.72
19.0GHz; Pol 21.0°	.100	12.0*	7.00	7.34	7.72	5.41	5.74	5.83
Ele 38.6°; R-Zone K	.030	23.0*	14.50	12.23	13.36	9.74	11.75	11.82
TYPE(B); 12 months	.010	42.0*	24.00	18.82	20.02	16.67	22.80	22.47
	.003	70.0*	45.00	28.60	30.59	25.43	39.99	38.45
	.001	100.0*	-1.00	40.27	43.04	33.18	59.22	55.74
Holmdel USA	1.000	2.0*	4.00	3.94	4.20	2.03	1.81	1.84
(40.4, -74.1) .11km	.300	6.0*	8.00	7.56	8.41	5.75	5.52	5.60
28.6GHz; Pol 69.0°	.100	12.0*	14.00	12.82	13.48	10.51	11.16	11.34
Ele 38.6°; R-Zone K	.030	23.0*	28.00	21.36	23.33	17.90	21.61	21.90
TYPE(B); 12 months	.010	42.0*	44.00	32.86	34.96	29.10	39.81	39.80
	.003	70.0*	-1.00	49.95	53.41	42.50	66.85	65.54
	.001	100.0*	-1.00	70.32	75.16	53.79	96.01	92.49
Lenox USA	1.000	2.0*	1.20	1.39	1.48	.44	.39	.41
(39.6, -79.3) .61km	.300	6.0*	2.40	2.66	2.96	1.51	1.52	1.57
11.6GHz; Pol .0°	.100	12.0*	4.80	4.52	4.74	3.04	3.55	3.58
Ele 18.0°; R-Zone K	.030	23.0*	9.40	7.53	8.21	5.60	7.90	7.10
TYPE(R); 12 months	.010	42.0*	-1.00	11.58	12.31	9.87	16.53	13.18
	.003	70.0*	-1.00	17.60	18.80	15.37	30.95	22.07
	.001	100.0*	-1.00	24.78	26.46	20.28	47.94	31.55
Palmetto USA	1.000	4.0*	-1.00	3.90	3.79	2.27	1.92	2.41
(33.3, -84.4) .10km	.300	11.0*	-1.00	7.47	7.60	6.17	5.73	7.12
19.0GHz; Pol 90.0°	.100	22.0*	10.00	12.66	12.18	11.57	12.12	14.04
Ele 29.9°; R-Zone M	.030	40.0*	-1.00	21.11	21.08	18.97	23.13	24.92
TYPE(B); 12 months	.010	63.0*	-1.00	32.47	31.59	26.81	37.79	38.34
	.003	95.0*	-1.00	49.36	48.25	35.65	58.91	56.42
	.001	120.0*	-1.00	69.49	67.91	39.84	75.83	70.20

STATION INFORMATION	TIME %	RAIN RATE	ATTEN (dB)	CCIR	FEDI	FRENCH	LIN	SAM
				PREDICTIONS				
Palmetto USA	1.000	4.0*	-1.00	3.01	2.85	1.53	1.29	1.61
(33.3, -84.4) .10km	.300	11.0*	-1.00	5.76	5.72	4.31	3.86	4.84
19.0GHz; Pol 90.0°	.100	22.0*	9.00	9.77	9.16	8.39	8.20	10.26
Ele 49.5°; R-Zone M	.030	40.0*	-1.00	16.29	15.86	14.34	15.71	19.43
TYPE(B); 12 months	.010	63.0*	-1.00	25.06	23.76	20.99	25.73	31.41
	.003	95.0*	-1.00	38.09	36.29	28.88	40.19	48.32
	.001	120.0*	-1.00	53.62	51.08	33.14	51.80	61.66
Palmetto USA	1.000	4.0*	-1.00	7.27	7.08	5.14	4.35	5.44
(33.3, -84.4) .10km	.300	11.0*	-1.00	13.94	14.19	13.01	12.08	15.03
28.6GHz; Pol 90.0°	.100	22.0*	20.00	23.64	22.74	23.23	24.35	28.47
Ele 29.9°; R-Zone M	.030	40.0*	-1.00	39.40	39.35	36.55	44.57	48.85
TYPE(B); 12 months	.010	63.0*	-1.00	60.62	58.97	50.05	70.56	73.23
	.003	95.0*	-1.00	92.14	90.08	64.68	106.88	105.24
	.001	120.0*	-1.00	129.73	126.78	71.12	135.36	129.20
Palmetto USA	1.000	4.0*	-1.00	5.60	5.31	3.47	2.92	3.66
(33.3, -84.4) .10km	.300	11.0*	-1.00	10.74	10.65	9.09	8.15	10.22
28.6GHz; Pol 90.0°	.100	22.0*	18.00	18.20	17.06	16.84	16.47	20.70
Ele 49.5°; R-Zone M	.030	40.0*	-1.00	30.34	29.54	27.58	30.22	37.72
TYPE(B); 12 months	.010	63.0*	-1.00	46.68	44.26	39.10	47.93	59.23
	.003	95.0*	-1.00	70.95	67.61	52.26	72.72	88.78
	.001	120.0*	-1.00	99.89	95.15	58.98	92.19	111.61
Tampa USA	1.000	5.0*	-1.00	4.63	4.10	1.89	1.47	2.12
(27.6, -82.3) .00km	.300	15.0*	-1.00	8.88	8.22	5.85	4.86	7.01
19.0GHz; Pol 90.0°	.100	35.0*	21.00	15.05	13.17	13.52	12.22	17.47
Ele 54.5°; R-Zone N	.030	65.0*	-1.00	25.09	22.80	23.74	23.95	33.75
TYPE(B); 12 months	.010	95.0*	-1.00	38.60	34.16	32.16	36.19	50.38
	.003	140.0*	-1.00	58.67	52.19	43.32	55.18	75.70
	.001	180.0*	-1.00	82.60	73.45	50.81	72.53	98.44
Tampa USA	1.000	5.0*	1.00	5.01	4.43	1.98	1.54	2.22
(27.6, -82.3) .00km	.300	15.0*	-1.00	9.60	8.89	6.20	5.15	7.43
19.0GHz; Pol .0°	.100	35.0*	30.00	16.28	14.25	14.46	13.07	18.67
Ele 54.5°; R-Zone N	.030	65.0*	-1.00	27.14	24.66	25.57	25.80	36.29
TYPE(B); 12 months	.010	95.0*	-1.00	41.75	36.95	34.79	39.15	54.38
	.003	140.0*	-1.00	63.46	56.45	47.06	59.94	82.02
	.001	180.0*	-1.00	89.34	79.44	55.35	79.00	106.93
Wallops Island USA	1.000	1.8	2.20	6.76	6.85	1.77	1.57	1.70
(37.8, -75.5) .00km	.300	6.8	6.30	12.96	13.74	6.33	6.02	6.53
28.6GHz; Pol 90.0°	.100	14.0	13.00	21.98	22.02	11.93	12.52	13.57
Ele 41.6°; R-Zone K	.030	36.0	-1.00	36.64	38.11	27.39	32.60	34.70
TYPE(B); 12 months	.010	70.6	-1.00	56.37	57.11	47.93	64.52	66.88
	.003	70.0*	-1.00	85.68	87.24	41.40	63.96	66.33
	.001	100.0*	-1.00	120.63	122.77	52.44	91.82	93.52
Wallops Island USA	1.000	3.8	2.90	6.02	6.08	3.60	3.17	3.44
(37.8, -75.5) .00km	.300	9.4	7.50	11.54	12.19	8.39	7.95	8.62
28.6GHz; Pol 90.0°	.100	19.8	15.50	19.56	19.52	16.26	16.93	18.41
Ele 44.5°; R-Zone K	.030	38.0	-1.00	32.60	33.80	27.90	32.79	35.35
TYPE(B); 12 months	.010	65.0	-1.00	50.16	50.64	42.70	56.51	60.04
	.003	70.0*	-1.00	76.24	77.36	40.27	60.92	64.56
	.001	100.0*	-1.00	107.33	108.87	51.19	87.47	91.44

STATION INFORMATION	TIME %	RAIN RATE	ATTEN (dB)	CCIR	FEDI	FRENCH	LIN	SAM
				PREDICTIONS				
Wallops Island USA	1.000	2.4	3.30	5.33	5.39	2.26	1.99	2.16
(37.8, -75.5) .00km	.300	6.2	8.10	10.22	10.80	5.50	5.21	5.65
28.6GHz; Pol 90.0°	.100	14.3	17.70	17.33	17.30	11.69	12.17	13.24
Ele 44.5°; R-Zone K	.030	32.2	-1.00	28.89	29.95	23.59	27.72	29.98
TYPE(B); 12 months	.010	57.7	-1.00	44.45	44.88	37.84	50.08	53.41
	.003	70.0*	-1.00	67.56	68.56	40.27	60.92	64.56
	.001	100.0*	-1.00	95.12	96.48	51.19	87.47	91.44
Waltham USA	1.000	3.8	-1.00	1.76	1.88	.83	.73	.73
(42.4, -71.3) .00km	.300	6.0*	-1.00	3.37	3.78	1.29	1.27	1.26
11.7GHz; Pol 45.0°	.100	19.0	2.10	5.71	6.05	4.58	5.17	4.78
Ele 24.0°; R-Zone K	.030	23.0*	-1.00	9.52	10.47	4.87	6.52	5.88
TYPE(B); 12 months	.010	58.0	10.30	14.65	15.69	12.78	20.10	15.73
	.003	70.0*	-1.00	22.27	23.97	13.50	25.27	19.16
	.001	96.0	-1.00	31.36	33.73	17.02	37.12	26.65
Waltham USA	1.000	3.7	-1.00	1.33	1.42	.80	.70	.70
(42.4, -71.3) .00km	.300	6.0*	-1.00	2.54	2.85	1.29	1.27	1.26
11.7GHz; Pol 45.0°	.100	16.0	1.80	4.31	4.56	3.72	4.19	3.96
Ele 24.0°; R-Zone K	.030	23.0*	-1.00	7.18	7.90	4.87	6.52	5.88
TYPE(B); 12 months	.010	46.0	8.20	11.05	11.83	9.64	15.16	12.32
	.003	70.0*	-1.00	16.79	18.08	13.50	25.27	19.16
	.001	86.0	15.30	23.65	25.44	14.89	32.47	23.76
Waltham USA	1.000	2.8	-1.00	2.41	2.58	1.43	1.25	1.25
(42.4, -71.3) .00km	.300	6.0*	-1.00	4.61	5.16	3.06	2.90	2.89
19.0GHz; Pol .0°	.100	14.0	3.00	7.82	8.27	7.01	7.38	7.33
Ele 35.5°; R-Zone K	.030	23.0*	-1.00	13.04	14.32	10.59	12.77	12.52
TYPE(B); 12 months	.010	42.0	28.00	20.06	21.46	18.04	24.82	23.71
	.003	70.0*	-1.00	30.48	32.78	27.38	43.62	40.39
	.001	90.0	-1.00	42.92	46.14	31.68	57.57	52.36
Waltham USA	1.000	3.0	2.10	2.94	3.14	1.44	1.25	1.25
(42.4, -71.3) .00km	.300	6.0*	-1.00	5.64	6.30	2.86	2.69	2.68
19.0GHz; Pol .0°	.100	18.0	7.50	9.56	10.10	8.69	9.05	9.01
Ele 38.5°; R-Zone K	.030	23.0*	-1.00	15.94	17.48	10.01	11.86	11.76
TYPE(B); 12 months	.010	53.0	18.70	24.52	26.19	22.15	29.78	28.75
	.003	70.0*	-1.00	37.26	40.01	26.14	40.48	38.55
	.001	93.0	-1.00	52.46	56.30	31.48	55.37	51.91
Waltham USA	1.000	2.8	-1.00	4.03	4.31	3.07	2.68	2.67
(42.4, -71.3) .00km	.300	6.0*	-1.00	7.72	8.65	6.13	5.80	5.78
28.6GHz; Pol 90.0°	.100	14.0	7.20	13.10	13.85	12.98	13.67	13.62
Ele 35.5°; R-Zone K	.030	23.0*	-1.00	21.83	23.98	18.73	22.59	22.36
TYPE(B); 12 months	.010	42.0	-1.00	33.58	35.93	30.20	41.56	40.34
	.003	70.0*	-1.00	51.04	54.89	43.75	69.70	66.01
	.001	90.0	-1.00	71.86	77.25	49.46	89.89	83.89
Waltham USA	1.000	3.0	4.00	4.87	5.20	3.08	2.69	2.68
(42.4, -71.3) .00km	.300	6.0*	-1.00	9.33	10.42	5.76	5.42	5.40
28.6GHz; Pol 90.0°	.100	18.0	18.80	15.81	16.70	15.84	16.49	16.51
Ele 38.6°; R-Zone K	.030	23.0*	-1.00	26.36	28.90	17.84	21.13	21.14
TYPE(B); 12 months	.010	53.0	-1.00	40.55	43.31	36.63	49.23	48.37
	.003	70.0*	-1.00	61.63	66.16	42.17	65.25	63.47
	.001	93.0	-1.00	86.77	93.11	49.51	87.00	83.58

6.2 Scattergrams

The performance of each of the five models can be graphically illustrated by scattergrams of measured attenuations versus a predicted attenuations. These scattergrams here shown in figures 6-1 to 6-5. In each figure, we can visually observe the spreading of data, which is necessarily large at high probability levels (1% and 0.3%) and small at low probability levels (0.003% and 0.001%), and the tendency of overprediction/underprediction, can be shown by data points above or below the 45° regression line. For instance, at 1% and 0.3% of times, the CCIR model generally overpredict the measured attenuation while the SAM model underpredict the measured attenuation. The spread for the two models appeared to be comparable. At 0.001% of time, the CCIR, FEDI, and FRENCH models show good convergence to the regression line but the LIN and SAM models show obvious overprediction. Except those obvious cases, there lies the difficulty of comparing the relative advantages and shortcomings among the five models by inspecting the scattergrams. An algorithm for quantitative comparison must be established. This will be given in Section 6.3

Figure 6-1 Scattergram for CCIR Model

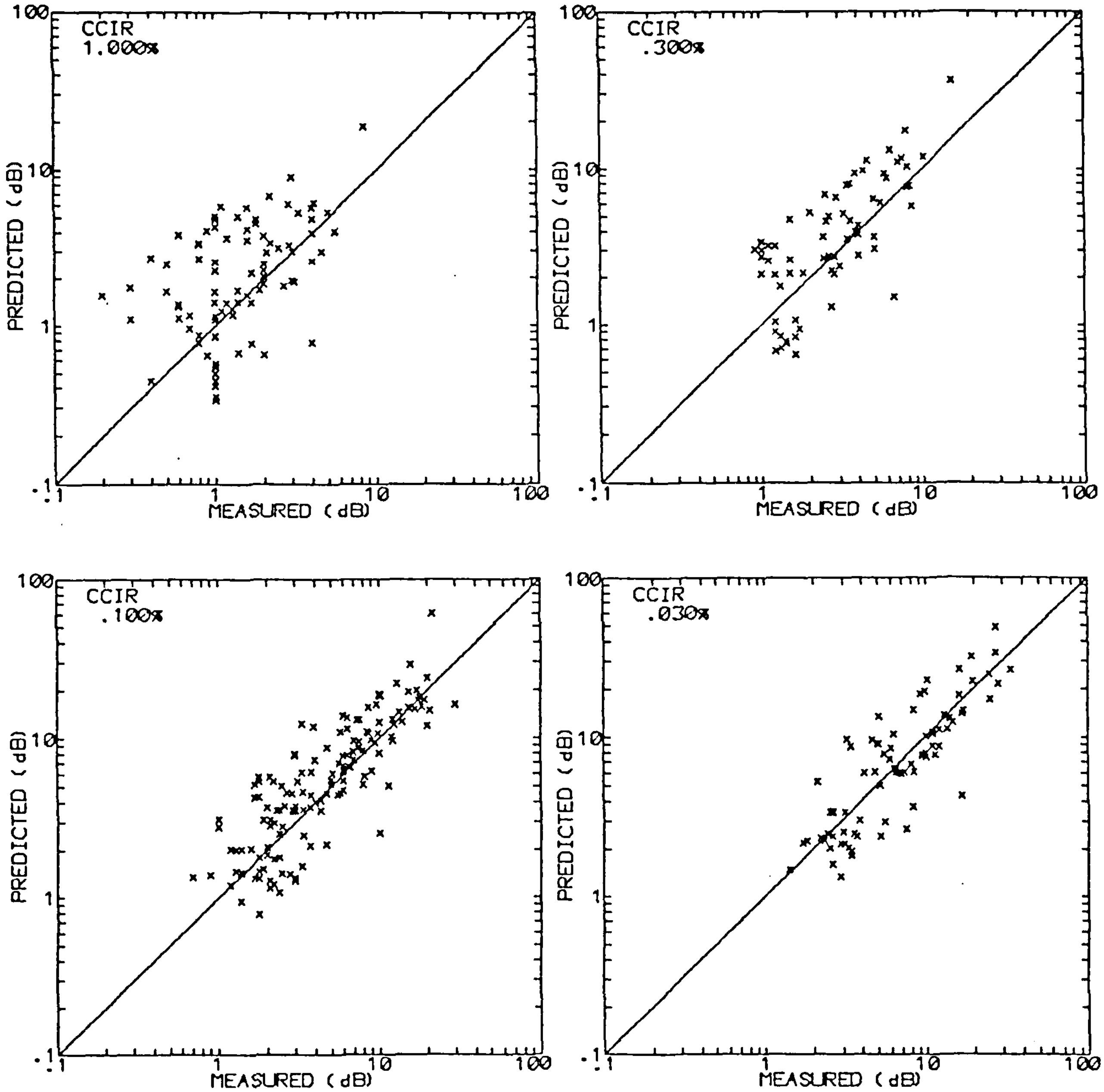


Figure 6-1 (Continue)

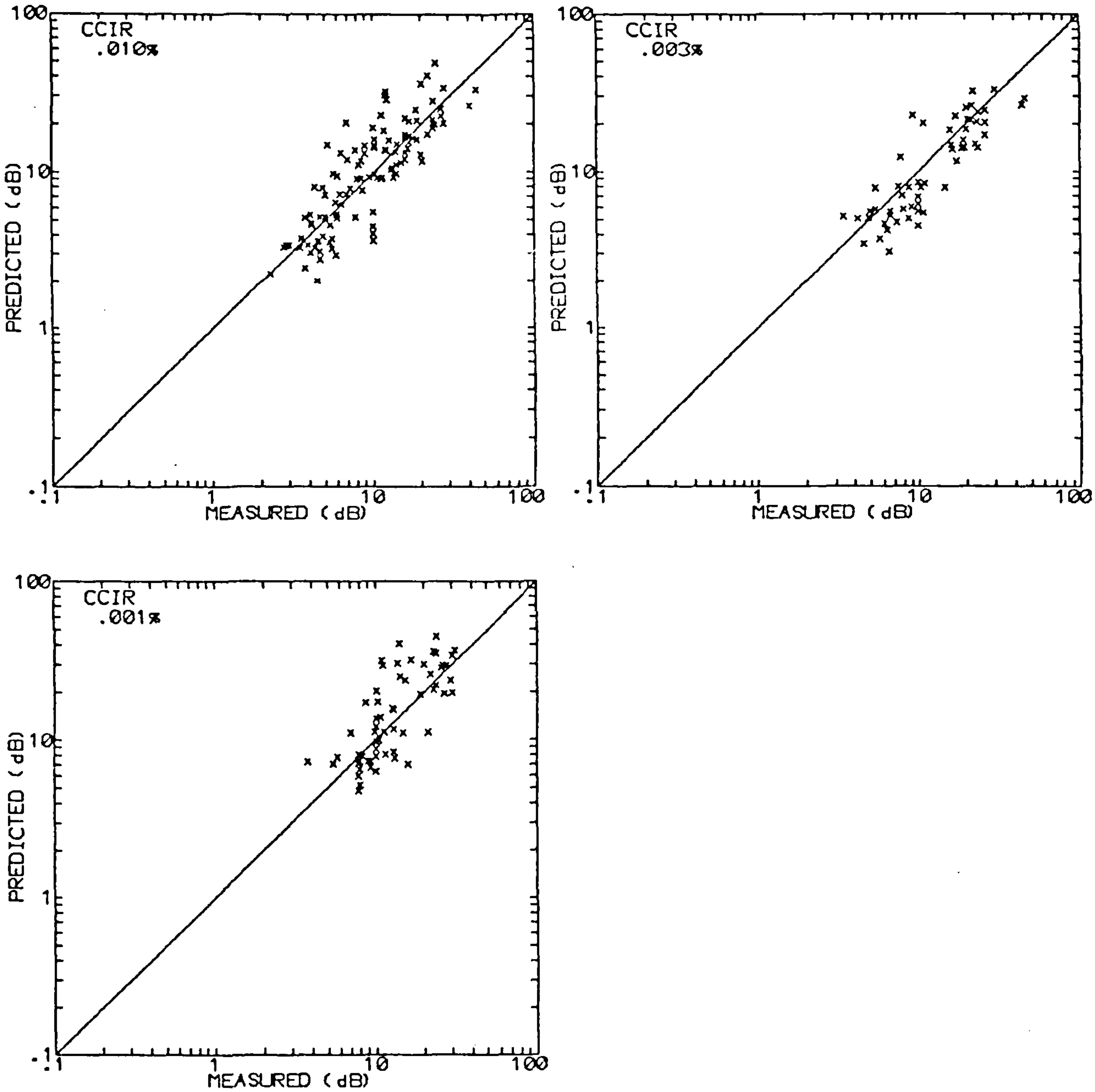


Figure 6-2 Scattergram of FEDI Model

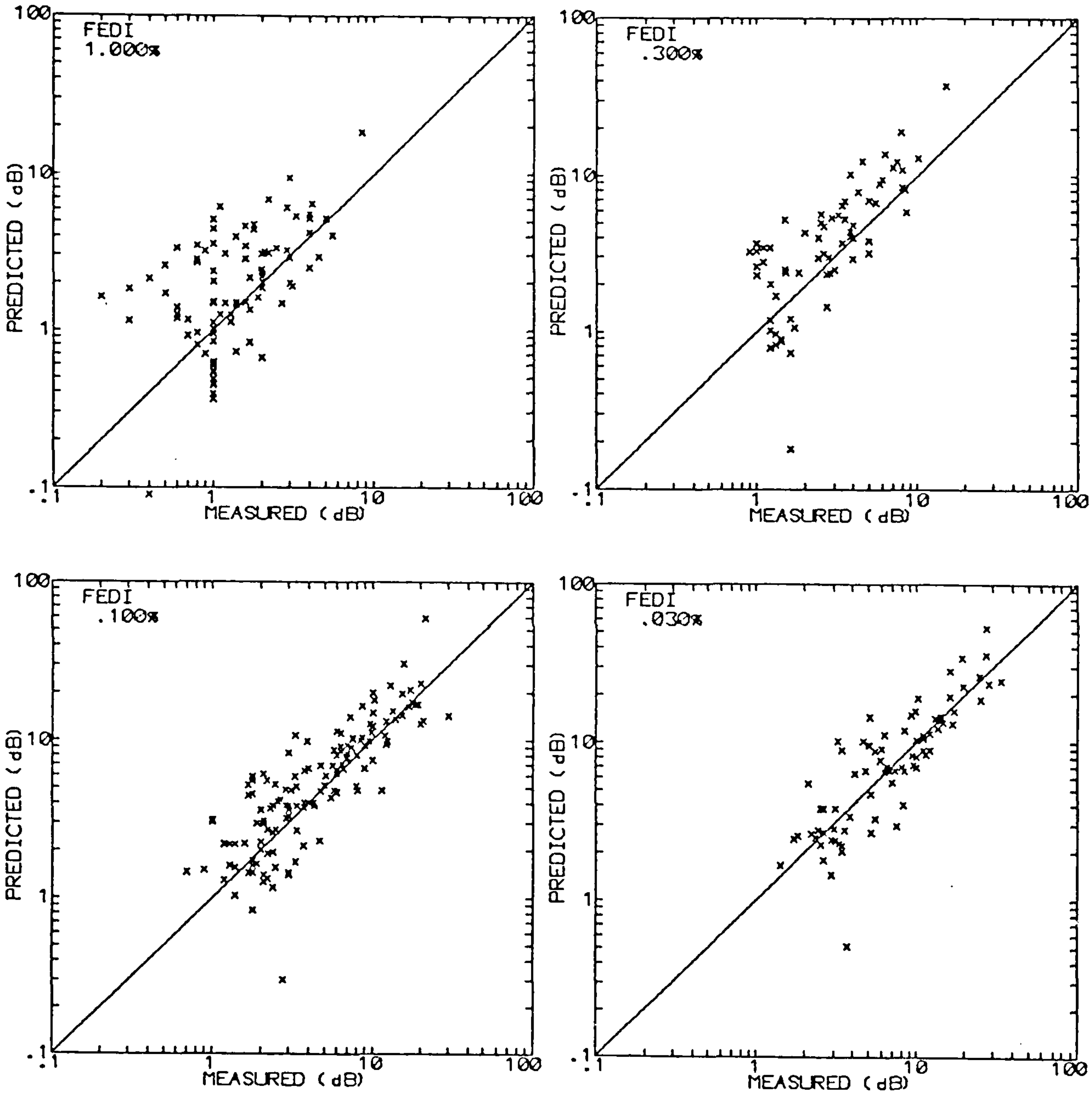


Figure 6-2 (Continue)

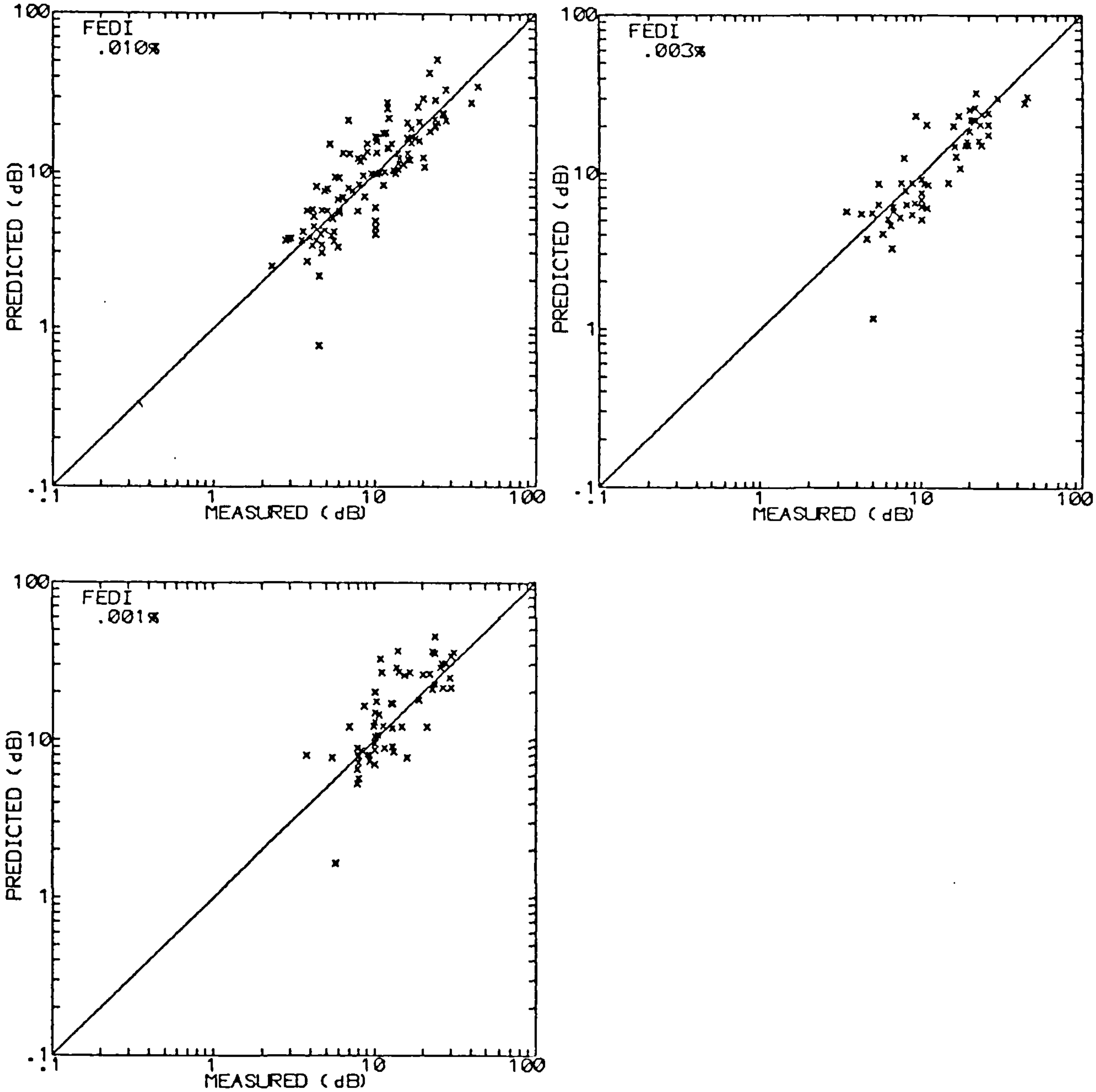


Figure 6-3 Scattergram of FRENCH Model

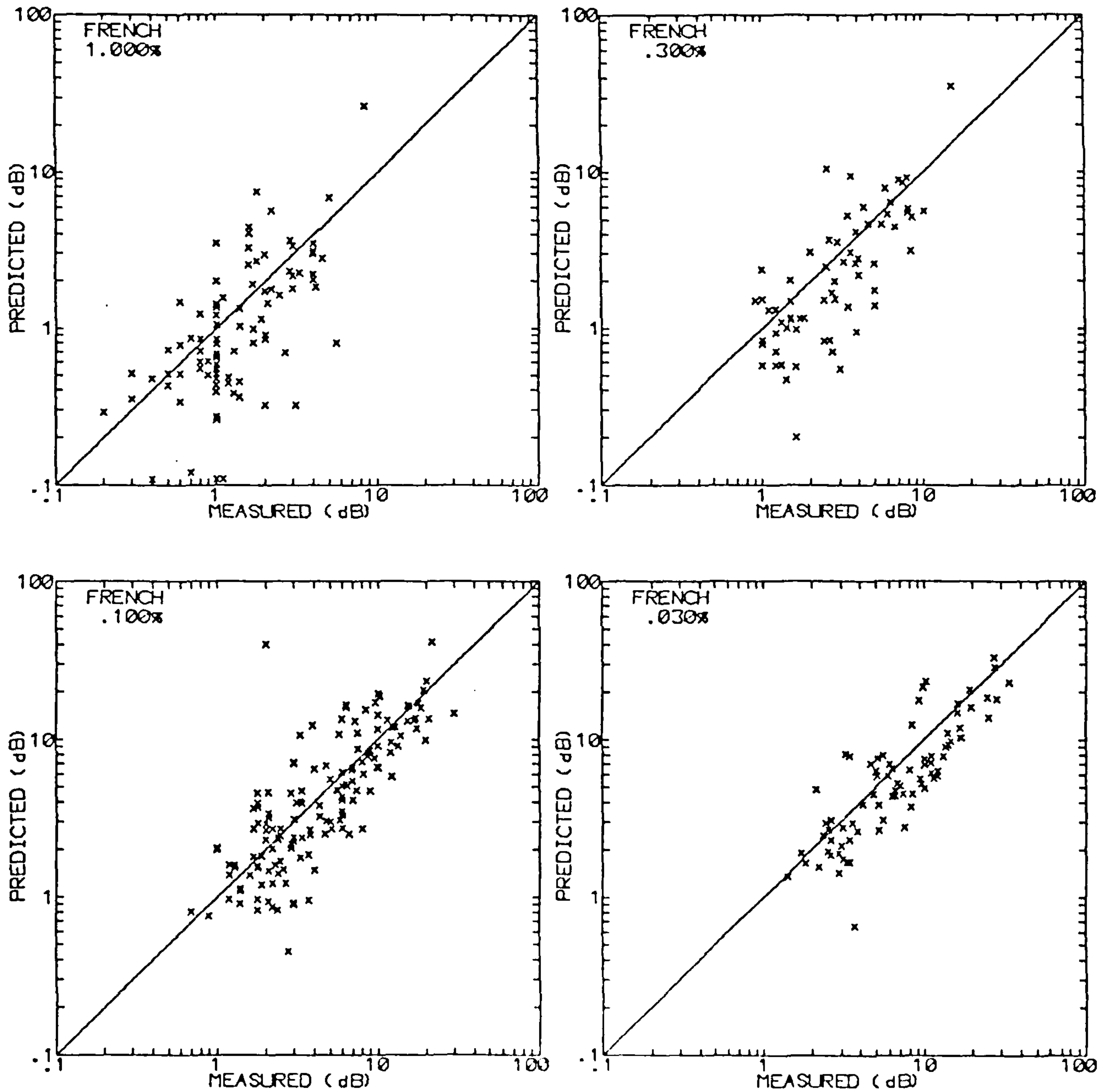


Figure 6-3 (Continue)

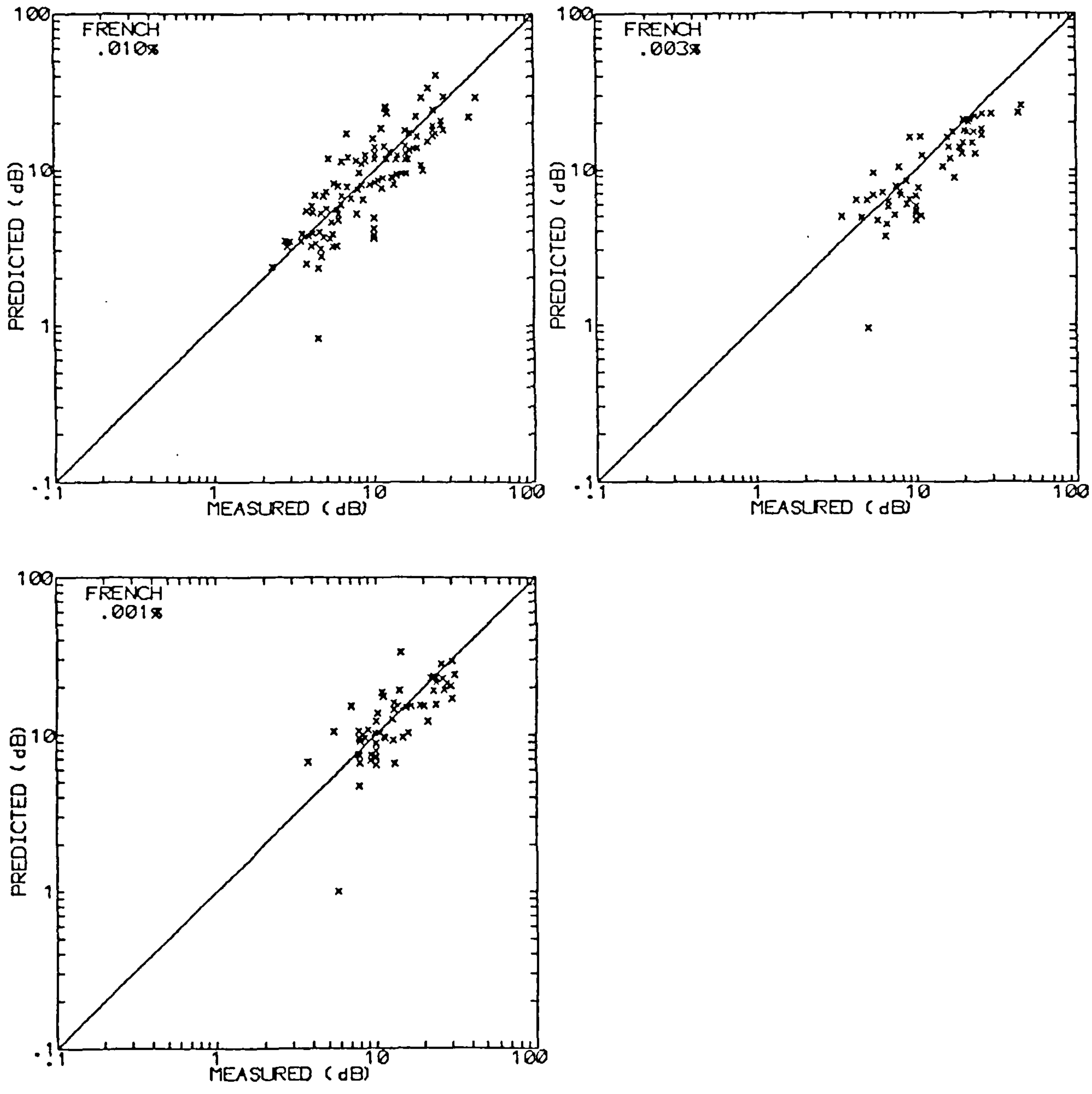


Figure 6-4 Scattergram of Lin Model

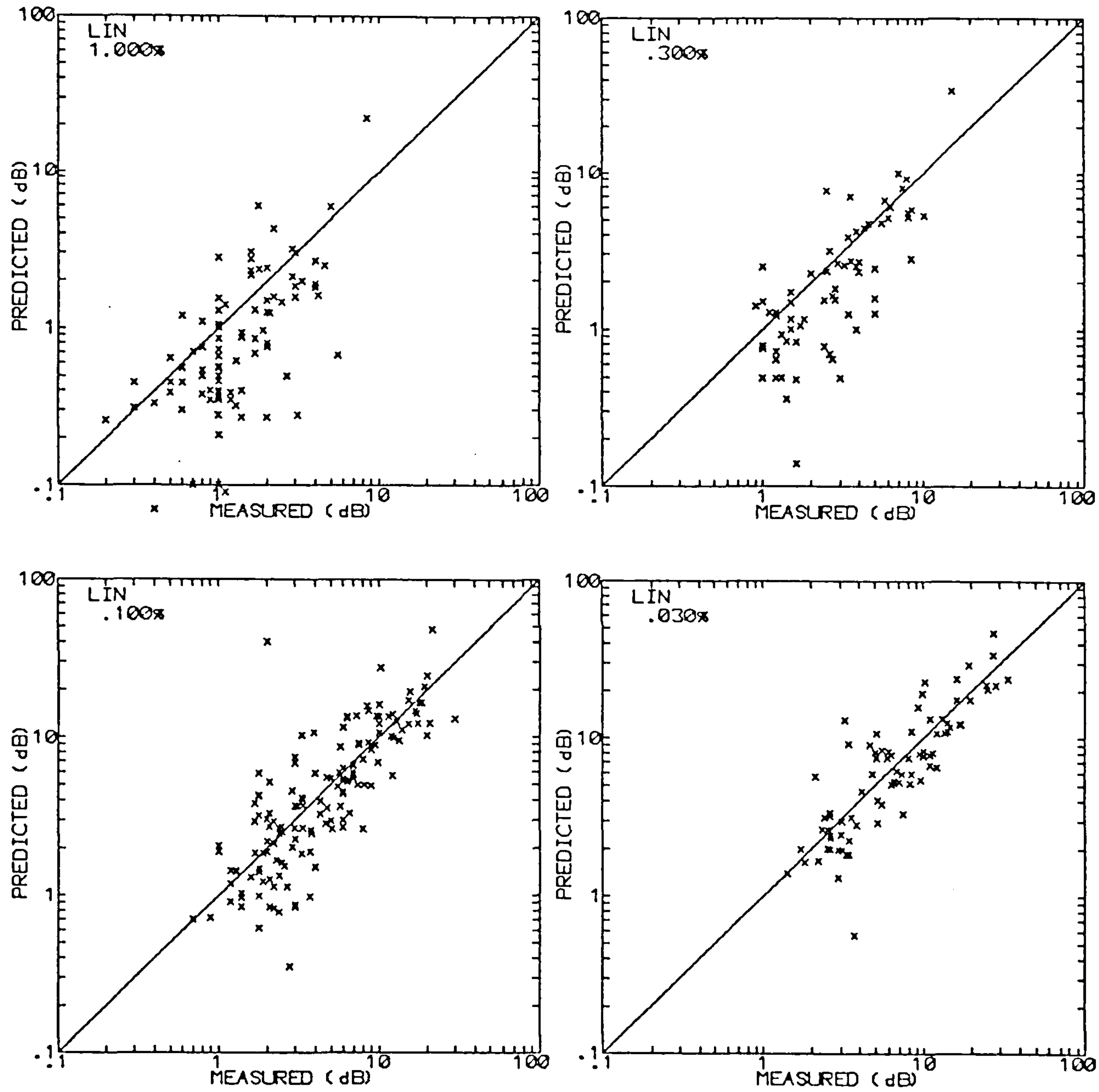
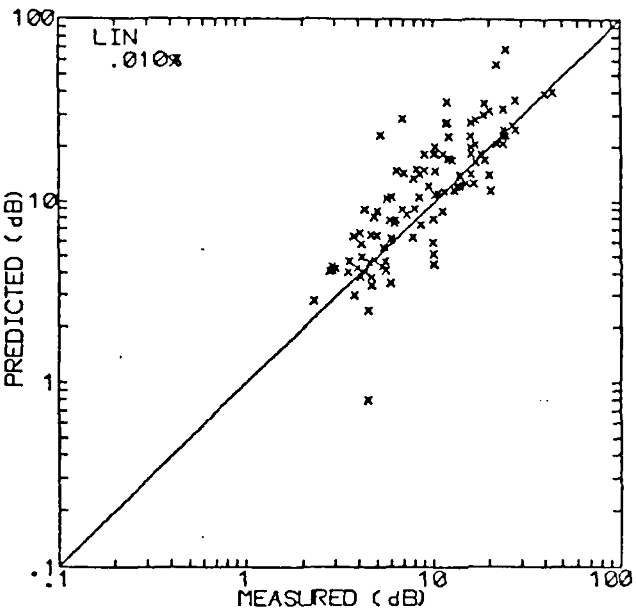
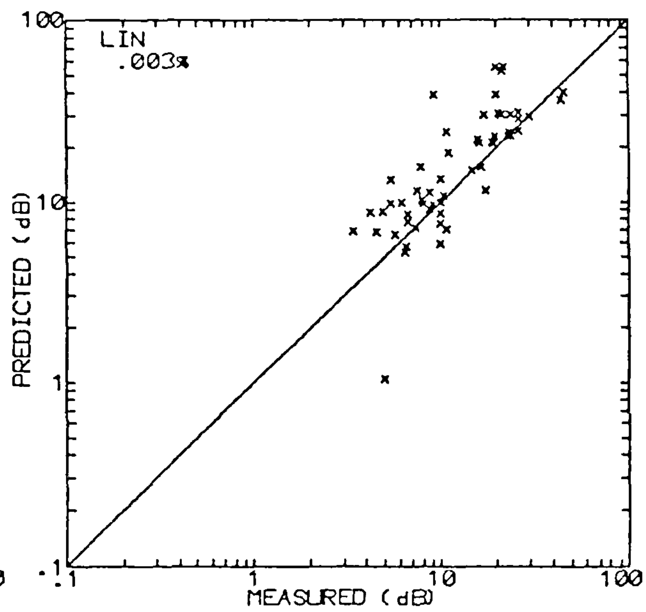


Figure 6-4 (Continue)





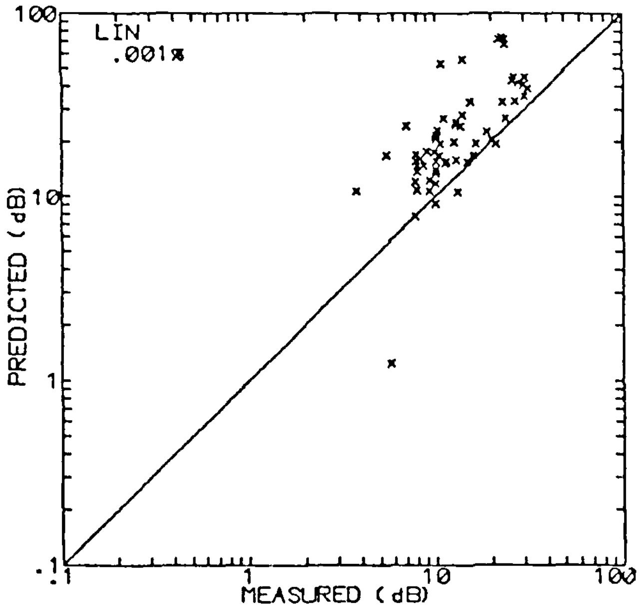


Figure 6-5 Scattergram of SAM Model

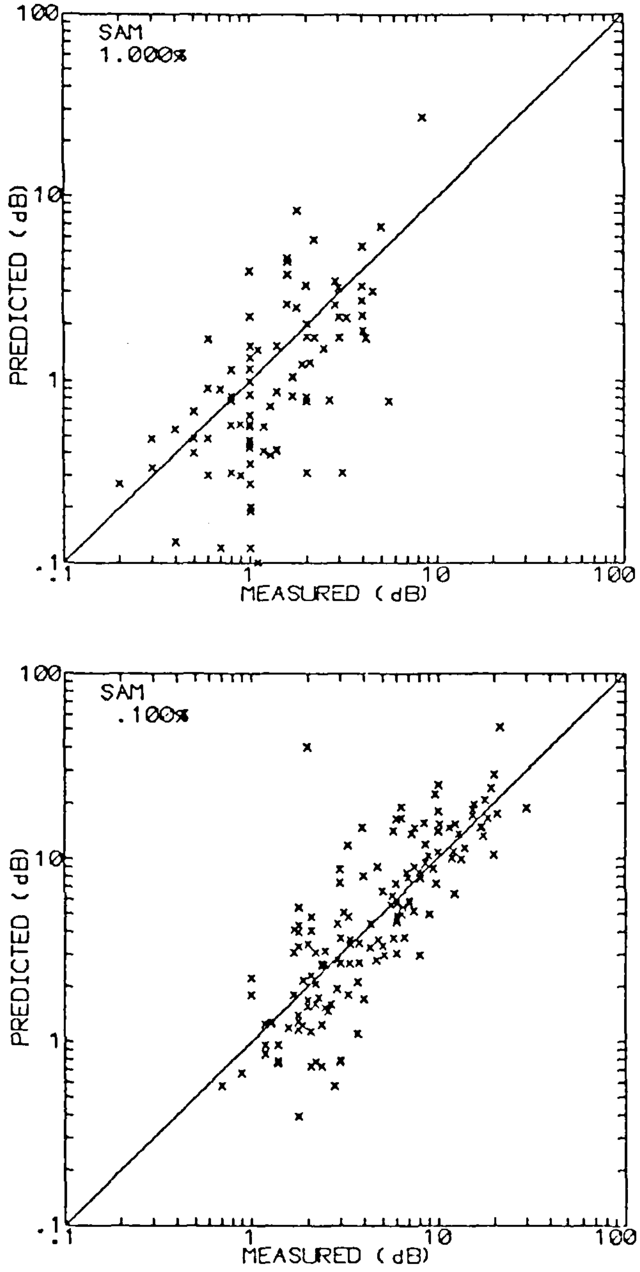
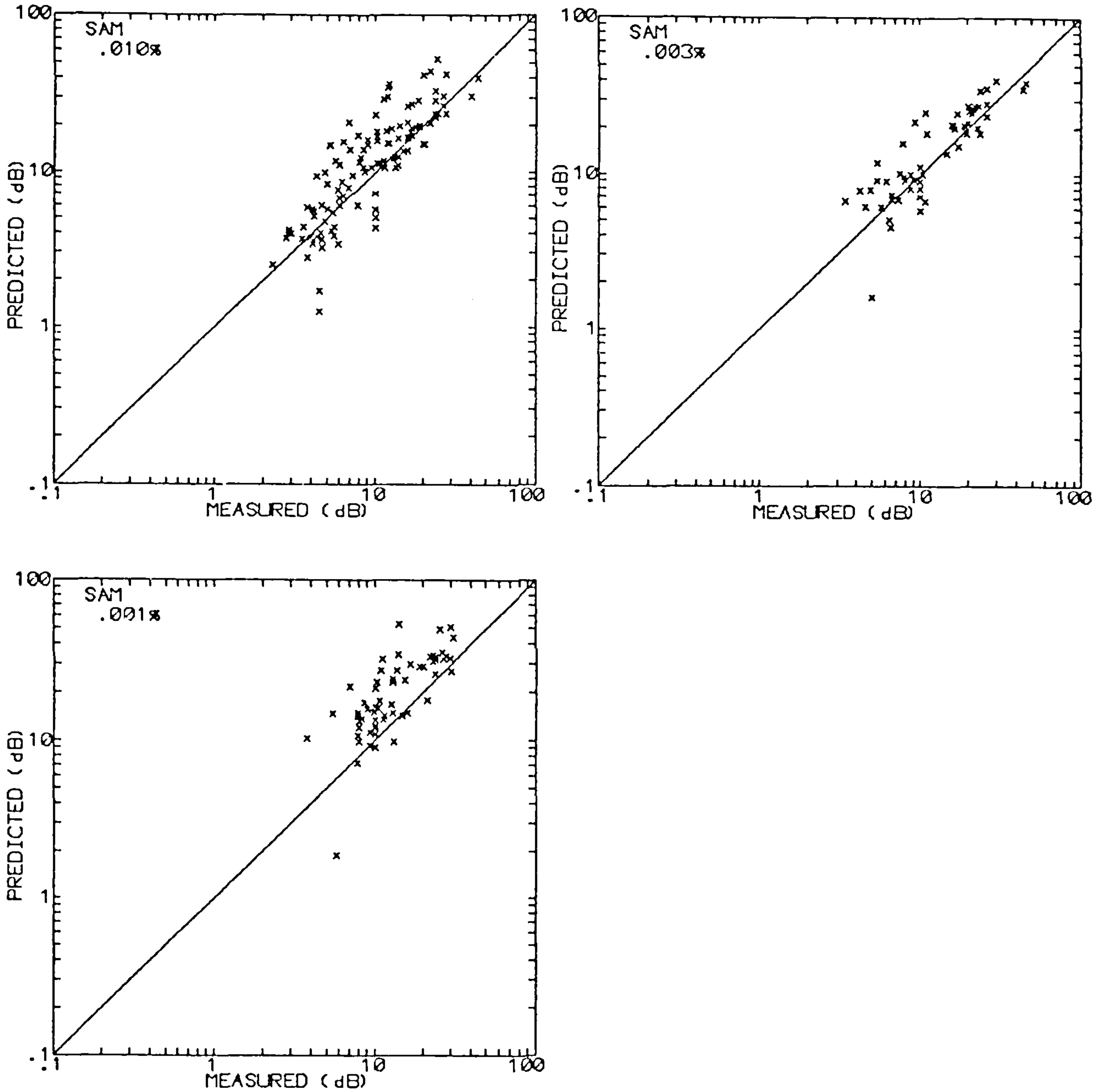


Figure 6-5 (Continue)



6.3 Quantative Model Comparison

For the sake of quantative comparison, we choose the algorithm as established by CCIR report 721. The algorithm first involves the evaluation of the difference between the predicted and measured attenuation in dB, as calculated for each path. The percentage of the difference to the measured attenuation is used as a test variable. To suppress the effect of measurement inaccuracy, the difference is set to zero if the predicted and measured values differ by 1 (dB) or less. The mean and standard deviation of the test variable is then calculated to provide the statistics for prediction method comparison. The computation procedure is as follow:

Step 1 - For each percentage of time, calculate the difference between the predicted attenuation A_p (dB) and measured attenuation A_m (dB) for each radio link:

$$d_i = A_p - A_m$$

where d_i is the difference calculated for the i radio link.

Step 2 - If $|A_p - A_m| < 1$ dB set $d_i = 0$

Step 3 - Calculate the test variable (%):

$$V_i = (d_i/A_m) \times 100$$

Step 4 - Calculate the mean μ_v and standard deviation σ_v of V_i values

Step 5 - Compute the root-mean-square plus one standard deviation score, S:

$$S = (\mu^2 + \sigma^2)^{1/2}$$

Step 6 - Repeat the procedure and calculate S for each percentage of time.

Although there is not much of a justification in step 2 for the omission of errors within 1 dB, particularly for frequencies below 6 GHz, this

omission appears to be a common practice as being carried out in many literatures. We note that the state-of-the-art of measuring signal attenuations, either by direct beacon measurement or by indirect radiometry, is still such that ambiguities do exist within 1 dB irrespect of frequencies.

Once the meteorology for model comparison is established, the statistical comparison can be applied to none categories of data, as summarized in Table 6-2.

All these statistical comparison tables are given in the sequel. These tables contain the mean prediction error (%), the standard deviation of the prediction error (%), and the rms plus one standard deviation score (%), obtained from the corresponding mean and standard deviation, for each model at seven time percentages. The mean deviation indicates whether a given model tends to underpredict (negative error), or overpredict (positive error) the attenuation at a specific time percentage. The magnitude of the corresponding standard deviation indicates how consistently the predictions follow the mean behavior: the greater the standard deviation, the more random the prediction process. The rms plus one standard deviation serves as the overall score of model performance. In the comparison of prediction methods, the best prediction method produces the smallest score values.

The asterisks (*) in Table 6-3 denotes the best performance at each time percentage. LIN model is found to score the best at 1% and 0.3% of the time levels. FRENCH model performs best at 0.1% through 0.001% of the time levels. If an overall rating is presumed to be given by the arithmetic mean of the seven score values for each model, the order of best performance are: FRENCH (48.70%); SAM (65.69%); LIN (67.64%); FEDI (77.46%); and CCIR (78.80%). The performance characteristics of the CCIR and FEDI models are quite similar at all time percentages. They are found to score the poorest among the 5 selected models. However, this overall rating is dominated by the large contribution at 1% and 0.3% time levels, which are the least significant time percentages for most rain attenuation predictions. If the average score is recomputed using only time percentages at 0.001% through 0.1%, the best performance order becomes: FRENCH (43.66%); FEDI (54.50%); CCIR (55.03%); SAM (63.79%); and LIN (74.80%).

Furthermore from the mean deviations in Table 6-3, six of the seven models, except FRENCH model, are observed to overpredict at most of the time percentage levels, except at 4 different cases, they underpredict by less then 10%. FRENCH model generally tends to underpredict at most time percentage levels and only overpredict at 1% and 0.1 time percentage levels for about 5%.

Results obtained from USA dataset shown in Table 6-4 are quite similar to those obtained from CCIR dataset. For entire percentile levels, the order of best performance are: FRENCH (39.65%); SAM (48.05%); LIN (64.78%); CCIR (76.45%); and FEDI (81.33%). If the score is recomputed using only time percentages of 0.001% through 0.1%, the best performance order becomes: FRENCH (33.31%); SAM (41.38%); CCIR (44.67%); FEDI (47.81%); and LIN (70.82%).

Similar observations can be made for results shown in Tables 6-5 to 6-11. The Lin model generally performs well for high probability cases (1% and 0.3%), but becomes unacceptable at the case of extreme low probability (0.001%). French model reflects the best fitting model for most cases. The general trend of identifying the best model is given in Table 6-12. A good rule of thumb appears to be of employing the Lin model for 1% and 0.3% of time, and applying the French model for the rest of percentiles.

Table 6.2 Categories of Data Used for Scoring the Models

Data Category	Definition	Table No.
All Data	All data around the world	6-3
USA Data	All locations in Continental US	6-4
Low Rain Region	For rainzones A to D (0.01% Rain-rate less than 20 mm/hr)	6-5
Medium Rain Region	For rain zone E to J (0.01% Rain-rate between 20 and 40 mm/hr)	6-6
High Rain Region	For rain zone K to L (0.01% Rain-rate between 40 and 60 mm/hr)	6-7
Extremely High Rain Region	For rain zone M to P (0.01% rain-rate over 60 mm/hr)	6-8
Low Elevation Angel Paths	For slant path angle below 20°	6-9
Medium Elevation Angle Paths	For slant path angle between 20° and 40°	6-10
High Elevation Angle Paths	For slant path angle above 40°	6-11

Table 6-3 Statistical Comparison of Models for All Data
(* indicates best performance model)

ALL DATA

CCIR	PROBABILITY	MEAN(%)	STD(%)	RMS(%)	DATA POINTS
	1.000	88.99	158.12	181.44	92
	.300	55.13	77.40	95.02	70
	.100	30.34	66.60	73.19	144
	.030	10.85	52.62	53.73	82
	.010	11.18	50.06	51.30	112
	.003	-9.36	36.17	37.36	56
	.001	20.27	56.02	59.57	60

FEDI	PROBABILITY	MEAN(%)	STD(%)	RMS(%)	DATA POINTS
	1.000	81.02	149.11	169.70	92
	.300	55.66	83.08	100.00	70
	.100	28.14	64.96	70.80	144
	.030	15.99	54.04	56.35	82
	.010	10.81	47.77	48.98	112
	.003	-5.29	38.22	38.59	56
	.001	21.60	53.61	57.80	60

FRENCH	PROBABILITY	MEAN(%)	STD(%)	RMS(%)	DATA POINTS
	1.000	5.39	62.60	62.83	92
	.300	-2.86	59.70	59.77	70
	.100	5.70	56.32	56.61*	144
	.030	-8.57	46.08	46.87*	82
	.010	-.70	41.11	41.11*	112
	.003	-14.18	31.80	34.82*	56
	.001	-.98	38.87	38.88*	60

LIN	PROBABILITY	MEAN(%)	STD(%)	RMS(%)	DATA POINTS
	1.000	-4.53	49.13	49.34*	92
	.300	-9.79	49.17	50.14*	70
	.100	6.75	57.40	57.79	144
	.030	6.48	56.89	57.26	82
	.010	31.54	63.86	71.22	112
	.003	36.33	64.90	74.38	56
	.001	77.88	82.35	113.34	60

SAM	PROBABILITY	MEAN(%)	STD(%)	RMS(%)	DATA POINTS
	1.000	11.23	72.26	73.12	92
	.300	1.31	67.74	67.75	70
	.100	17.06	66.51	68.66	144
	.030	7.94	58.00	58.54	82
	.010	27.60	56.36	62.75	112
	.003	19.17	42.30	46.44	56
	.001	55.94	60.72	82.56	60

Table 6-4 Statistical Comparison of Models for Continental US data
(* indicates best performance model)

USA DATA

CCIR	PROBABILITY	MEAN(%)	STD(%)	RMS(%)	DATA POINTS
	1.000	124.74	179.48	218.57	38
	.300	56.11	74.46	93.23	43
	.100	32.29	62.94	70.74	62
	.030	11.10	43.51	44.91	42
	.010	8.47	45.19	45.98	39
	.003	-9.30	23.94	25.68	22
	.001	14.54	32.95	36.02	15

FEDI	PROBABILITY	MEAN(%)	STD(%)	RMS(%)	DATA POINTS
	1.000	130.31	184.50	225.88	38
	.300	62.85	83.32	104.37	43
	.100	34.48	66.61	75.01	62
	.030	17.32	47.98	51.01	42
	.010	11.33	48.63	49.93	39
	.003	-8.17	24.03	25.39	22
	.001	16.81	33.78	37.73	15

FRENCH	PROBABILITY	MEAN(%)	STD(%)	RMS(%)	DATA POINTS
	1.000	-1.24	74.41	74.42	38
	.300	-19.03	31.22	36.57*	43
	.100	-12.25	44.62	46.27*	62
	.030	-20.22	26.07	32.99*	42
	.010	-7.08	38.20	38.86*	39
	.003	-22.35	17.00	28.07*	22
	.001	-12.45	16.10	20.35*	15

LIN	PROBABILITY	MEAN(%)	STD(%)	RMS(%)	DATA POINTS
	1.000	-10.49	61.88	62.76*	38
	.300	-21.38	29.68	36.58	43
	.100	-6.09	50.35	50.71	62
	.030	.94	37.64	37.65	42
	.010	36.31	67.96	77.05	39
	.003	37.79	57.52	68.83	22
	.001	92.22	76.55	119.85	15

SAM	PROBABILITY	MEAN(%)	STD(%)	RMS(%)	DATA POINTS
	1.000	6.54	91.67	91.90	38
	.300	-16.65	33.64	37.54	43
	.100	-.26	47.55	47.55	62
	.030	1.36	30.84	30.87	42
	.010	23.37	45.34	51.01	39
	.003	16.30	23.52	28.62	22
	.001	40.37	27.54	48.87	15

Table 6-5 Statistical Comparison of Models for Low Rain Region
(* indicates best performance model)

RAIN ZONE A-D

CCIR	PROBABILITY	MEAN(%)	STD(%)	RMS(%)	DATA POINTS
	1.000	-	-	-	6
	.300	-8.77	21.47	23.19	6
	.100	-24.86	27.47	37.05	6
	.030	-44.21	22.93	49.81	6
	.010	-45.35	23.24	50.96	6
	.003	-22.17	38.60	44.52*	6
	.001	6.37	45.79	46.23	6

FEDI	PROBABILITY	MEAN(%)	STD(%)	RMS(%)	DATA POINTS
	1.000	-	-	-	6
	.300	-7.78	19.05	20.58	6
	.100	-16.64	25.79	30.69	6
	.030	-39.59	21.29	44.96	6
	.010	-42.00	21.83	47.33	6
	.003	-13.34	42.81	44.84	6
	.001	15.81	50.06	52.50	6

FRENCH	PROBABILITY	MEAN(%)	STD(%)	RMS(%)	DATA POINTS
	1.000	-	-	-	6
	.300	-6.36	15.57	16.82*	6
	.100	-15.48	23.98	28.54	6
	.030	-40.78	22.52	46.58	6
	.010	-46.97	24.04	52.76	6
	.003	-30.06	36.58	47.35	6
	.001	-8.66	41.97	42.85*	6

LIN	PROBABILITY	MEAN(%)	STD(%)	RMS(%)	DATA POINTS
	1.000	-	-	-	6
	.300	-6.60	16.18	17.48	6
	.100	-13.93	21.64	25.74*	6
	.030	-33.89	18.90	38.80*	6
	.010	-26.68	36.13	44.91*	6
	.003	8.89	51.94	52.69	6
	.001	65.10	67.52	93.79	6

SAM	PROBABILITY	MEAN(%)	STD(%)	RMS(%)	DATA POINTS
	1.000	-	-	-	6
	.300	-6.85	16.78	18.13	6
	.100	-14.35	22.28	26.50	6
	.030	-36.45	19.61	41.39	6
	.010	-30.98	34.43	46.31	6
	.003	.26	48.97	48.97	6
	.001	45.66	64.85	79.31	6

Table 6-6 Statistical Comparison of Models for Medium Rain Region
(* indicates best performance model)

RAIN ZONE E-J

CCIR	PROBABILITY	MEAN(%)	STD(%)	RMS(%)	DATA POINTS
	1.000	-	-	-	6
	.300	79.44	123.08	146.49	6
	.100	15.77	75.00	76.64	26
	.030	12.64	64.17	65.40	23
	.010	3.05	49.18	49.28	29
	.003	-4.57	47.08	47.30	23
	.001	1.29	51.70	51.72	24

FEDI	PROBABILITY	MEAN(%)	STD(%)	RMS(%)	DATA POINTS
	1.000	-	-	-	6
	.300	86.61	134.19	159.72	6
	.100	18.51	73.63	75.92	26
	.030	26.03	65.97	70.92	23
	.010	8.00	48.99	49.64	29
	.003	3.97	47.27	47.44	23
	.001	8.67	52.70	53.40	24

FRENCH	PROBABILITY	MEAN(%)	STD(%)	RMS(%)	DATA POINTS
	1.000	-	-	-	6
	.300	11.83	66.15	67.20*	6
	.100	-.27	50.23	50.24*	26
	.030	6.50	55.38	55.76*	23
	.010	2.47	38.14	38.22*	29
	.003	2.17	35.82	35.88*	23
	.001	4.16	42.22	42.43*	24

LIN	PROBABILITY	MEAN(%)	STD(%)	RMS(%)	DATA POINTS
	1.000	-	-	-	6
	.300	.95	81.13	81.14	6
	.100	.36	64.90	64.90	26
	.030	19.88	82.19	84.56	23
	.010	30.59	71.61	77.87	29
	.003	51.26	74.60	90.51	23
	.001	76.99	92.56	120.39	24

SAM	PROBABILITY	MEAN(%)	STD(%)	RMS(%)	DATA POINTS
	1.000	-	-	-	6
	.300	3.54	89.88	89.95	6
	.100	-.51	65.36	65.36	26
	.030	12.51	73.56	74.61	23
	.010	11.03	52.75	53.89	29
	.003	32.65	51.81	61.24	23
	.001	51.96	60.65	79.87	24

Table 6-7 Statistical Comparison of Models for High Rain Region
(* indicates best performance model)

RAIN ZONE K-L

CCIR	PROBABILITY	MEAN(%)	STD(%)	RMS(%)	DATA POINTS
	1.000	83.10	161.39	181.53	49
	.300	48.88	73.78	88.50	42
	.100	35.12	61.42	70.75	73
	.030	14.47	42.36	44.77	42
	.010	12.05	41.82	43.52	57
	.003	-10.59	24.46	26.65	23
	.001	28.51	52.49	59.73	24

FEDI	PROBABILITY	MEAN(%)	STD(%)	RMS(%)	DATA POINTS
	1.000	89.02	169.14	191.13	49
	.300	58.56	83.38	101.89	42
	.100	38.24	64.80	75.24	73
	.030	21.67	46.22	51.05	42
	.010	15.33	43.39	46.02	57
	.003	-7.34	24.32	25.41*	23
	.001	30.43	48.34	57.12	24

FRENCH	PROBABILITY	MEAN(%)	STD(%)	RMS(%)	DATA POINTS
	1.000	-13.41	29.38	32.29*	49
	.300	-22.90	29.74	37.54	42
	.100	-5.50	44.72	45.06*	73
	.030	-17.25	27.62	32.56	42
	.010	-1.39	36.06	36.09*	57
	.003	-20.80	16.42	26.49	23
	.001	-1.62	34.26	34.29*	24

LIN	PROBABILITY	MEAN(%)	STD(%)	RMS(%)	DATA POINTS
	1.000	-19.76	32.21	37.78	49
	.300	-23.63	30.66	38.71	42
	.100	-.25	46.75	46.75	73
	.030	5.02	36.78	37.12	42
	.010	37.86	58.17	69.41	57
	.003	40.11	54.04	67.30	23
	.001	94.18	75.42	120.66	24

SAM	PROBABILITY	MEAN(%)	STD(%)	RMS(%)	DATA POINTS
	1.000	-15.41	30.21	33.91	49
	.300	-21.86	29.90	37.04*	42
	.100	3.39	47.30	47.42	73
	.030	1.59	32.06	32.10*	42
	.010	30.51	44.74	54.15	57
	.003	15.16	23.18	27.70	23
	.001	60.11	56.99	82.83	24

Table 6-8 Statistical Comparison of Models for Extremely High Rain Region
(* indicates best performance model)

RAIN ZONE M-P

CCIR	PROBABILITY	MEAN(%)	STD(%)	RMS(%)	DATA POINTS
	1.000	132.76	170.18	215.83	31
	.300	86.37	66.72	109.14	16
	.100	39.60	70.61	80.96	39
	.030	23.28	60.83	65.13	11
	.010	37.47	62.78	73.11	20
	.003	-10.63	18.60	21.42*	4
	.001	77.14	61.60	98.72	6

FEDI	PROBABILITY	MEAN(%)	STD(%)	RMS(%)	DATA POINTS
	1.000	99.74	136.31	168.91	31
	.300	60.23	67.70	90.61	16
	.100	22.54	60.54	64.60*	39
	.030	3.66	52.00	52.13*	11
	.010	17.82	55.81	58.58	20
	.003	-34.64	32.20	47.29	4
	.001	43.82	77.98	89.45	6

FRENCH	PROBABILITY	MEAN(%)	STD(%)	RMS(%)	DATA POINTS
	1.000	37.20	94.19	101.27	31
	.300	45.53	93.41	103.92	16
	.100	33.88	72.54	80.06	39
	.030	10.64	72.12	72.90	11
	.010	10.52	54.01	55.02*	20
	.003	-46.30	25.69	52.95	4
	.001	-11.29	46.27	47.63*	6

LIN	PROBABILITY	MEAN(%)	STD(%)	RMS(%)	DATA POINTS
	1.000	17.77	69.01	71.26*	31
	.300	21.30	68.21	71.46*	16
	.100	27.31	69.28	74.47	39
	.030	6.05	65.04	65.32	11
	.010	32.38	68.95	76.17	20
	.003	-30.08	35.94	46.87	4
	.001	28.99	74.43	79.87	6

SAM	PROBABILITY	MEAN(%)	STD(%)	RMS(%)	DATA POINTS
	1.000	57.70	104.57	119.43	31
	.300	64.34	100.52	119.35	16
	.100	59.17	83.58	102.41	39
	.030	46.82	88.75	100.35	11
	.010	60.90	74.50	96.22	20
	.003	-6.98	45.21	45.74	4
	.001	65.51	83.89	106.44	6

Table 6-9 Statistical Comparison of Models for Low Elevation Angle Paths
(* indicates best performance model)

ELEVATION 0.- 20.

CCIR	PROBABILITY	MEAN(%)	STD(%)	RMS(%)	DATA POINTS
	1.000	60.04	155.40	166.59	12
	.300	28.32	86.18	90.71	11
	.100	36.74	93.47	100.43	18
	.030	-2.63	73.89	73.94	10
	.010	25.84	80.29	84.35	11
	.003	22.12	61.53	65.38	7
	.001	69.67	65.47	95.61	6

FEDI	PROBABILITY	MEAN(%)	STD(%)	RMS(%)	DATA POINTS
	1.000	47.85	133.11	141.45	12
	.300	34.29	91.40	97.62	11
	.100	35.51	82.91	90.19	18
	.030	3.52	76.90	76.98	10
	.010	25.15	75.18	79.27	11
	.003	26.42	61.64	67.06	7
	.001	73.49	66.84	99.34	6

FRENCH	PROBABILITY	MEAN(%)	STD(%)	RMS(%)	DATA POINTS
	1.000	25.42	76.44	80.55	12
	.300	-.16	70.84	70.84*	11
	.100	14.73	79.10	80.46*	18
	.030	-25.66	63.06	68.08*	10
	.010	5.52	63.24	63.48*	11
	.003	-4.57	36.21	36.50*	7
	.001	6.87	30.88	31.64*	6

LIN	PROBABILITY	MEAN(%)	STD(%)	RMS(%)	DATA POINTS
	1.000	11.44	59.80	60.89*	12
	.300	3.34	72.33	72.41	11
	.100	33.64	91.09	97.10	18
	.030	13.94	104.41	105.34	10
	.010	82.51	110.20	137.67	11
	.003	129.77	103.72	166.13	7
	.001	220.10	93.33	239.07	6

SAM	PROBABILITY	MEAN(%)	STD(%)	RMS(%)	DATA POINTS
	1.000	25.83	80.14	84.20	12
	.300	10.41	80.06	80.73	11
	.100	25.99	88.86	92.58	18
	.030	-7.16	75.62	75.96	10
	.010	27.16	76.56	81.24	11
	.003	28.98	50.23	57.99	7
	.001	63.13	44.98	77.51	6

Table 6-10 Statistical Comparison of Models for Medium Elevation Angle Paths
(* indicates best performance model)

ELEVATION 20. - 40.

CCIR	PROBABILITY	MEAN(%)	STD(%)	RMS(%)	DATA POINTS
	1.000	67.73	144.27	159.37	36
	.300	46.94	77.07	90.23	32
	.100	29.72	66.28	72.64	66
	.030	6.66	46.18	46.66	48
	.010	.42	42.58	42.58	60
	.003	-18.51	24.72	30.88*	40
	.001	-.58	36.41	36.41*	43

FEDI	PROBABILITY	MEAN(%)	STD(%)	RMS(%)	DATA POINTS
	1.000	72.69	151.34	167.89	36
	.300	49.96	89.97	102.91	32
	.100	32.56	69.89	77.10	66
	.030	14.90	49.63	51.82	48
	.010	4.63	45.80	46.04	60
	.003	-13.25	28.91	31.80	40
	.001	3.72	39.57	39.75	43

FRENCH	PROBABILITY	MEAN(%)	STD(%)	RMS(%)	DATA POINTS
	1.000	-2.26	38.13	38.19	36
	.300	-8.94	42.70	43.63	32
	.100	2.12	49.44	49.48*	66
	.030	-10.36	34.48	36.01*	48
	.010	-6.11	37.58	38.07*	60
	.003	-16.60	31.35	35.47	40
	.001	-3.85	42.56	42.73	43

LIN	PROBABILITY	MEAN(%)	STD(%)	RMS(%)	DATA POINTS
	1.000	-8.60	31.85	32.99*	36
	.300	-14.08	37.61	40.16*	32
	.100	3.77	50.85	50.99	66
	.030	3.13	41.15	41.27	48
	.010	25.33	61.08	66.13	60
	.003	22.60	43.78	49.27	40
	.001	62.11	69.11	92.92	43

SAM	PROBABILITY	MEAN(%)	STD(%)	RMS(%)	DATA POINTS
	1.000	-3.35	39.91	40.05	36
	.300	-11.54	45.05	46.51	32
	.100	5.05	52.28	52.53	66
	.030	-.85	40.29	40.30	48
	.010	11.54	46.27	47.69	60
	.003	12.15	38.72	40.58	40
	.001	45.47	62.97	77.67	43

Table 6-10 Statistical Comparison of Models for Medium Elevation Angle Paths
(* indicates best performance model)

ELEVATION 20. - 40.

CCIR	PROBABILITY	MEAN(%)	STD(%)	RMS(%)	DATA POINTS
	1.000	67.73	144.27	159.37	36
	.300	46.94	77.07	90.23	32
	.100	29.72	66.28	72.64	66
	.030	6.66	46.18	46.66	48
	.010	.42	42.58	42.58	60
	.003	-18.51	24.72	30.88*	40
	.001	-.58	36.41	36.41*	43

FEDI	PROBABILITY	MEAN(%)	STD(%)	RMS(%)	DATA POINTS
	1.000	72.69	151.34	167.89	36
	.300	49.96	89.97	102.91	32
	.100	32.56	69.89	77.10	66
	.030	14.90	49.63	51.82	48
	.010	4.63	45.80	46.04	60
	.003	-13.25	28.91	31.80	40
	.001	3.72	39.57	39.75	43

FRENCH	PROBABILITY	MEAN(%)	STD(%)	RMS(%)	DATA POINTS
	1.000	-2.26	38.13	38.19	36
	.300	-8.94	42.70	43.63	32
	.100	2.12	49.44	49.48*	66
	.030	-10.36	34.48	36.01*	48
	.010	-6.11	37.58	38.07*	60
	.003	-16.60	31.35	35.47	40
	.001	-3.85	42.56	42.73	43

LIN	PROBABILITY	MEAN(%)	STD(%)	RMS(%)	DATA POINTS
	1.000	-8.60	31.85	32.99*	36
	.300	-14.08	37.61	40.16*	32
	.100	3.77	50.85	50.99	66
	.030	3.13	41.15	41.27	48
	.010	25.33	61.08	66.13	60
	.003	22.60	43.78	49.27	40
	.001	62.11	69.11	92.92	43

SAM	PROBABILITY	MEAN(%)	STD(%)	RMS(%)	DATA POINTS
	1.000	-3.35	39.91	40.05	36
	.300	-11.54	45.05	46.51	32
	.100	5.05	52.28	52.53	66
	.030	-.85	40.29	40.30	48
	.010	11.54	46.27	47.69	60
	.003	12.15	38.72	40.58	40
	.001	45.47	62.97	77.67	43

Table 6-11 Statistical Comparison of Models for High Elevation Angle Paths
(* indicates best performance model)

ELEVATION 40. - 60.

CCIR	PROBABILITY	MEAN(%)	STD(%)	RMS(%)	DATA POINTS
	1.000	114.28	168.89	203.93	44
	.300	75.76	71.63	104.26	27
	.100	29.10	58.13	65.01	60
	.030	24.83	54.21	59.62	24
	.010	23.01	47.89	53.13	41
	.003	6.81	39.96	40.54	9
	.001	74.85	64.75	98.97	11

FEDI	PROBABILITY	MEAN(%)	STD(%)	RMS(%)	DATA POINTS
	1.000	96.88	152.50	180.67	44
	.300	71.11	70.51	100.14	27
	.100	21.07	52.71	56.77	60
	.030	23.38	53.00	57.92	24
	.010	16.01	41.04	44.05	41
	.003	5.42	42.34	42.69	9
	.001	63.21	57.03	85.13	11

FRENCH	PROBABILITY	MEAN(%)	STD(%)	RMS(%)	DATA POINTS
	1.000	6.19	73.85	74.11	44
	.300	3.23	72.58	72.65	27
	.100	6.92	56.15	56.57	60
	.030	2.13	56.90	56.94*	24
	.010	5.53	38.88	39.27*	41
	.003	-10.89	32.49	34.26*	9
	.001	5.96	26.55	27.22*	11

LIN	PROBABILITY	MEAN(%)	STD(%)	RMS(%)	DATA POINTS
	1.000	-5.57	57.29	57.56*	44
	.300	-10.06	51.20	52.18*	27
	.100	1.97	49.91	49.95*	60
	.030	10.07	60.09	60.92	24
	.010	26.96	44.52	52.04	41
	.003	24.67	53.00	58.46	9
	.001	61.95	45.87	77.08	11

SAM	PROBABILITY	MEAN(%)	STD(%)	RMS(%)	DATA POINTS
	1.000	19.19	88.36	90.42	44
	.300	12.82	83.16	84.14	27
	.100	27.58	71.67	76.79	60
	.030	31.81	73.74	80.31	24
	.010	51.22	56.86	76.52	41
	.003	42.71	46.37	63.04	9

Table 6-12 Best Model Tabulation

		CCIR	FEDI	FRENCH	LIN	SAM
	1				*	
	0.3				*	
Overall	0.1			*		
data	0.03			*		
	0.01			*		
	0.003			*		
	0.001			*		
	1				*	
	0.3			*		
USA	0.1			*		
Data	0.03			*		
	0.01			*		
	0.003			*		
	0.001			*		
	1					
	0.3			*		
	0.1				*	
Low Rain	0.03				*	
Data	0.01				*	
	0.003	*				
	0.001			*		
	1					
	0.3			*		
Moderate	0.1			*		
Rain	0.03			*		
Data	0.01			*		
	0.003			*		
	0.001			*		
	1			*		
	0.3					*
High Rain	0.1			*		
Data	0.03					*
	0.01			*		
	0.003		*			
	0.001			*		
	1				*	
Extremely	0.3				*	
High Rain	0.1		*			
Data	0.03		*			
	0.01			*		
	0.003	*				
	0.001			*		

Table 6-12 Best Model Tabulation (continue)

		CCIR	FEDI	FRENCH	LIN	SAM
	1				*	
	0.3			*		
Low Angle	0.1			*		
Data	0.03			*		
	0.01			*		
	0.003			*		
	0.001			*		
	1				*	
	0.3				*	
Moderate	0.1			*		
Angle	0.03			*		
Data	0.01			*		
	0.003	*				
	0.001	*				
	1				*	
	0.3				*	
High	0.1				*	
Angle	0.03			*		
Data	0.01			*		
	0.003			*		
	0.001			*		

7. Discussion and Conclusion

7.1 The Inconclusiveness of Models

Rain attenuation prediction models have been available for more than ten years. From chronological viewpoint, at least a dozen models can be named [Dutton, 1984]. Even with the selection of the 5 most well recognized models given in this report, it is apparent that the present state of modeling is somewhat unsatisfactory and inconclusive in most aspects. For example, two of the models that are most explicit in accounting for site-specific parameters (latitude and site elevation), namely the CCIR model and the Simple Model, perform the poorest overall. Conversely, two models that largely ignore such adjustments, the French and Lin models are the best performers overall.

Furthermore, no discernible advantage is detected in parameterizing the effective path length in terms of time percentage or rain rate. Both approaches can yield good (French model) or poor (CCIR and SAM models) performance. This result was unanticipated, since using rain rate was intuitively expected to represent the physical situation more accurately. Of course, the lack of a conclusive result may only be indicative of the current state of rain attenuation modeling.

The most significant finding of this study is the identification of weaknesses in the CCIR model. It is obvious that the CCIR method, even as adjusted by the additional reduction factor F_p, is not a superior performer. At time percentages near 1 percent, the performance is quite poor. Originally, it appeared that a primary weakness was the use of an effective path length based solely on time percentage; however, results of this analysis do not support this opinion. In addition, the use of the expression aR^b for specific attenuation cannot be a prime weakness because all of the models use this expression.

Two general characteristics of the CCIR model are apparent

a. A tendency to overpredict, with the bias being greater for time per-

centages most removed from 0.01 percent; and

b. rather large values of the standard deviation of the prediction error.

Taken together, these results indicate that the prime weakness of the model is the use of constant factors to extrapolate from the "base" time percentage (0.01%) to other time percentages. Such a procedure employs only a single point on the cumulative distribution of point rain rate, and therefore ignores completely the shape of this distribution. Thus, an important (perhaps crucial) aspect of site-specific conditions, namely the effects of stratiform and convective rainfall on local rain rate characteristics, is ignored. This approach of scaling from a single time percentage may also exaggerate any inherent weaknesses in using time percentage as the sole determinant of effective path length. A second weakness appears to be the form of the path reduction factors used in the model.

While the French model has the overall best performance, it comes as no surprise as it is purely a fitting model. The procedures, coefficients and equations are all designed deliberately with optimize fitting as the sole objective. As such, the meaning of equations (4-16) and (4-17) are difficult to comprehend from physical configuration viewpoint.

7.2 Identification of Areas for Immediate Model Improvement

Study areas that should be pursued to rectify, at least on an first order basis, these deficiencies of current attenuation models, include:

a. The model should be recast to use rain rate information for any time percentage of interest. This approach would return to the general formalism of the previous CCIR model, but the coefficients would have to be established differently and verified over the entire data set.

b. Implications of the height reduction factor and of the path reduction factor should be investigated, and alternate forms derived as necessary from independent information on the spatial structure of rainfall.

c. Particular problems associated with prediction of rain impairments in tropical climates should be investigated particularly in areas in conjunction with the rain height profile study. It is suspected that the use of a height reduction factor in tropical zones is at variance with current knowledge on this subject [Houze, 1981].

7.3 Recommended Procedures for Engineering Application

The discussion given in 7.1 and 7.2 appears to confirm the suspicion originally held by the US Air Force:

"Numerous studies have been previously conducted on this subject and vast amount of data exist in this regard; however, a wide range of uncertainty exists and the communications system designer is confronted with conflicting data".

On the other hand, we should not take an overly pessimistic view regarding the *applicability of models.* Most importantly, the prime concern raised by the US Air Force:

"Using existing rain propagation data, it is possible to show any condition from complete link outage to one of minimal or not effect"

is no longer there. This is clearly illustrate in Chapter 6, when detailed comparison of predicted values versus measured values are presented for all models. Although the 5 leading models do produce somewhat divergent predictive results, none of them would yield wild answers in the sense of "from complete link outage to one of minimal or no effect".

Specifically, as a rule of thumb, we recommend the use of Lin's model for percentage of time over 0.3% of a year, and for percentage of time less than 0.3%, the French model is considered to be applicable. For more specific applications, such as for cases of low rain-rate regions to high rain-rate regions, low elevation angle paths to high elevation angle paths, etc., best performance models are identified according to Table 6-12.

The methodology for applying these models have been clearly documented in Chapter 4.

7.4 Follow-up Work, the Phase 2 Suggestions

7.4.1 Phase 1 Accomplishment

The phase 1 accomplishment, as documented in this report, can be summarized as follows:

* Established a most up-to-dated database which is so far not available anywhere in the literature.

* Identified 5 leading models, each was thoroughly tested against the data base and thus pinpointed its limitations/weakness.

* Suggested directions for immediate model improvement.

* Provided the best overall model available at the present for BMO's application.

7.4.2 Phase 2 Objectives

The phase 1 work deals only with a phenomenon, i.e., rain effects on radio frequency propagation. While the work, successfully accomplished by MTL, is academically meaningful and significance, its usefulness to BMO's applications is still somewhat limited. An obvious next question to ask is

* What is the impact of rain effects on radio frequency systems?

furthermore, rain may not be the most significant meteorological concern for BMO's radio frequency systems, but general meteorological effects are. A more prudent second question to ask is

* What is the impact of general meteorological effects on radio frequency systems?

None of the above two questions is easy to answer, particularly so in terms of the BMO's requirement that any impact assessment has to be on a real time basis for immediate decision-making support. The simple truth is that knowledge/database, models and other analytic/software tools for real time system impact assessment on radio frequency systems are not yet in existence. Therefore, the phase II objectives can be clearly identified as:

The development of knowledge/database, models and analytic/software tools for real time impact assessment of rain and general meteorological effects on radio frequency systems.

7.4.3 Suggested Phase 2 Tasks

In order to meet the objectives, two specific tasks are issued.

7.4.3.1 Task 1 - The Development of Knowledge/Database, Models and Analytic/Software Tools for Real time Impact Assessment of Rain on Radio Frequency Systems

This is a direct extension of the phase I work which deals only with the phenomenon of rain effects on radio frequency propagation. This task addresses the real interest, i.e., the impact of that phenomenon to a radio frequency system. Here the system can be any system that of BMO's interest, including a communications system, a navigation system, a remote-sensing system, a tracking/surveillance system, or a jamming/anti-jamming system. In order to be able to make real time assessment, the following subtasks have to be performed:

Subtask 1.1 - Editing the database and prediction model for specific system of interest

While rain effects on RF propagation is a phenomenon, the phenomenon manifests itself differently for different type of systems. Results of the

phase 1 work have to be edited in a specific manner in order to study the system impact to a particular system of interest. For instance, rain-induced fading level is a concern to a communications system in determining the link margin; excess time delay when wave penetrate a precipitation cloud is a concern to a navigation system in determining the range and location; depolarization by rain is a concern to a remote-sensing system which uses dual polarization mode to sample the target; the non-stationary property of a rain medium is a concern to a tracking/surveillance system which has a requirement of setting proper dwell time when sweeping through the space; and common volume scattering due to the presence of a rain event is a concern to a jamming/anti-jamming system which has to be able to control the level of wanted to unwanted interference.

The editing work also includes an effort of continuous updating the database established in phase I as new information becomes available constantly at national and international level.

Subtask 1.2 - Quick look reference manual

Under this subtask, the work done by subtask 1.1 will be further extended with an orientation toward the specific system of interest. All types of rain-induced degradations, including but not limited to fade level, fade duration, depolarization discrimination, sky noise temperature increase, time delay, angle of arrival change, phase and frequency dispersion, doppler effects, scintillation, multipath, cochannel and cross-channel interference, common volume scattering, etc., will be evaluated with a priority order according to their significance to the particular system.

The evaluation will produce some fundamental and practical rule-of-thumbs which will be useful for real time system impact assessment. For instance:

* The evolution of an event in terms of how fast in time the maximum fade level will be reached, as required for diversity switching decisions.

* The magnitude and the speed of angle-of-arrival changes, as required for phase-array antenna tracking operations.

* The dominant frequency spectrum component in a rain-induced tropospheric scintillation event, as required for implementing the adaptive coding for correcting digital transmission errors.

* Signature of ice depolarization when no attenuation at all appears, as required for the initiation of polarization compensation techniques.

* Distortion of radar echoes resulting from rain-induced pulse dispersion and beam divergence, as required for radar detection corrections.

7.4.3.2 Task 2 - The Development of Knowledge/Database, Models, and Analytic/Software Tools for Real Time Impact Assessment of General Meteorological Effects on Radio Frequency Systems

The general meteorological effects to be considered here have a much more involved spatial and temporal dimensions than that of the rain events. For instance, for BMO's reentry vehicle testing applications, radio frequency tracking system and communications system have to be able to function in the presence of rain or moisture cloud masses, thunderstorms, internal gravity waves and clear air turbulence, all of which have to be predicted with a horizontal spatial scales of 2km to 20km and a time scale of the order of one-half of an hour to several hours. Under these circumstances, quick reference manuals, contour maps, analytic and simple software programs, such as those produced in task 1, are no longer applicable. The only way to go is the development of an artificial intelligent (AI) based expert system.

Under task 2, work will be performed to identify those applications that use empirical knowledge or procedures which can be formalized as knowledge-based modules for the expert system, including the human-machine interactive processing system, computer aided guidance or checklist, empiri-

cal indices or simply rules of thumb, etc. Some examples are listed below:

* An experimental algorithm developed by National Weather Services (NWS) that shows learning behavior has been devised to predict the possibility that a severe thunderstorm will occur.

* The basic steps used in the preparation of a Convective Outlook used by NWS/NSSFC include a "severe weather checklist" of 10 parameters which are evaluated as a group using IF-THEN rules to determine the possibility of a storm.

* A diagnostic procedure has been developed at the NWS National Hurricane Center for evaluating numerical guidance materials. Its principle element is a decision ladder that supplies a systematic means of formalizing prediction experience which in turn can be used to develop more effective prediction models.

* The PROF (Prototype Regional Observing and Forecasting Service) effort at NOAA/ERL is exploring the use of improved human/machine interactive capabilities, including the overlaying of displays from different sensors; the results of this effort should be applicable to the establishment of an interpretive processing capability.

* Forecasting aids such as for minimum temperatures, for precipitation type and SWEAT and SPOT indices - developed by the Air Force, is found to be valuable forecaster aids, especially so in an environment where individual forecaster retentivity is short and where the range of individual forecaster experience is very large.

All these examples are in its infancy stage and none of them is available on a microcomputer based system. The essence of the task 2 work is to custom-taylor important features of the above examples and others according to BMO's viewpoint for practical implementation on a microcomputer system. Further effort is then made for assessing the real time impact of these meteorological effects on radio frequency systems under scenariors that are of interest to BMO, such as the case of reentry vehicle testing.

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